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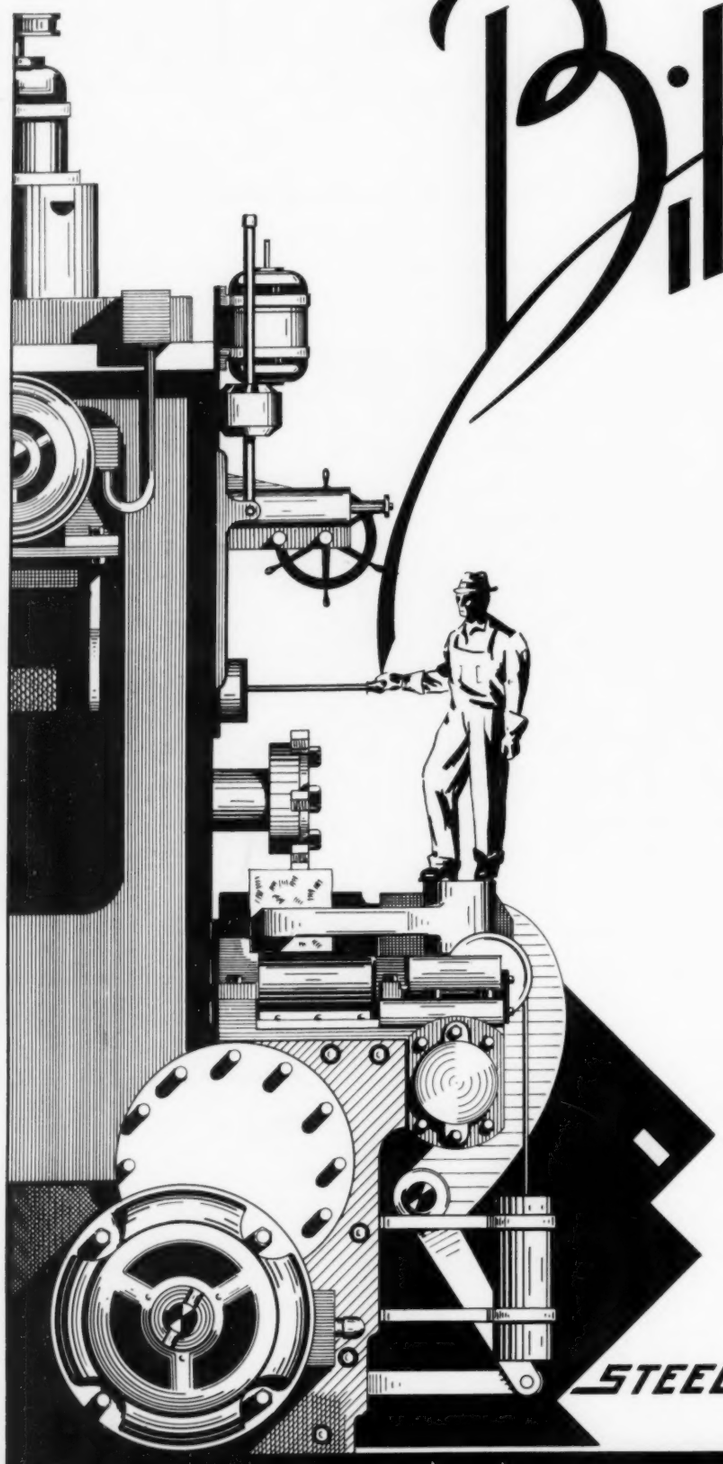

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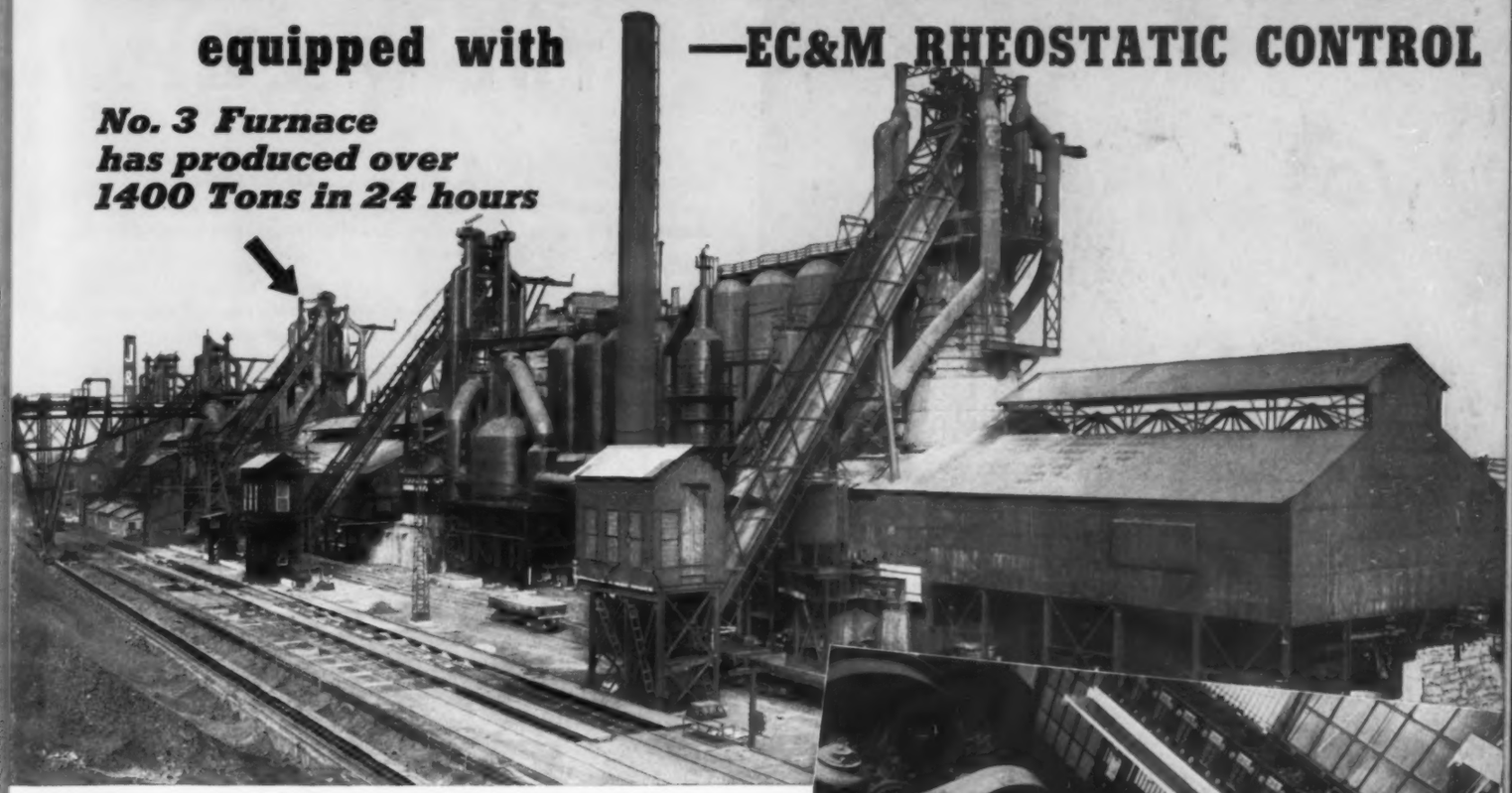

Interior view of one the skip-houses, showing EC&M Bulletin 920 LINE-ARC Magnetic Contactor Controller, EC&M Bulletin 940-A Nickel Alloy Resistors, EC&M Bulletin 1110-3 Traveling Nut Limit Switch and EC&M Bulletin 1004-B Type WB Brake on hoist motor.

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THE A. I. & S. E.

A number in excess of 900 took advantage of an invitation from the Jones & Laughlin Steel Corporation to visit its new 96" continuous hot and cold strip mill. This inspection trip was conducted under the auspices of the Pittsburgh Section of the Association on the afternoon of January 26. A total of eighteen buses were used to transport the guests from the William Penn Hotel to the plant.

The top left illustration shows (left) S. S. Marshall, Jr., vice president, Jones & Laughlin Steel Corporation, who arranged the trip, explaining to W. W. Knight, Jr., Morgan Construction Company, the many features of this new mill.

Among those attending the activities from the Youngstown Sheet & Tube Company were, (left) A. S. Glossbrenner, superintendent, hot strip mills and C. A. Davis, assistant general superintendent of Campbell Works, Youngstown Sheet & Tube Co., shown in the left center illustration. A general idea of the large number who attended the trip may be gleaned from the bottom left view.

C. L. McGranahan, assistant general superintendent, Jones & Laughlin Steel Corporation and L. F. Coffin, superintendent of Mechanical Department, Bethlehem Steel Company, Maryland plant and president of the Association, greet each other in

VISITS J & L

the top center view. Immediately below this can be seen Earl F. Blank, director Industrial Relations, Jones & Laughlin Steel Corporation, pointing out to H. P. Shields and J. W. Benner of the Homestead Works, Carnegie-Illinois Steel Corporation, some unusual aspects of the new strip mill.

Immediately following the trip the members and guests returned to the William Penn Hotel for dinner which was followed by the delivery of a paper by Professor W. Trinks, head of the Mechanical Engineering Department, Carnegie Institute of Technology, on the subject of his "Forty Years of Rolling Mill Engineering in the Steel Industry."

President Coffin, as shown in the upper right, also had a few words of comment regarding Association activities. Beneath Mr. Coffin is shown T. E. Hughes, Chairman of the Pittsburgh Section and Chief Maintenance Engineer, Carnegie-Illinois Steel Corporation, Duquesne, Pa., who had charge of this inspection trip and meeting, considered by many to be one of the most interesting events ever held by the Pittsburgh Section.

Other illustrations are those of the Speakers Table and various other groups who participated in the day's activities.

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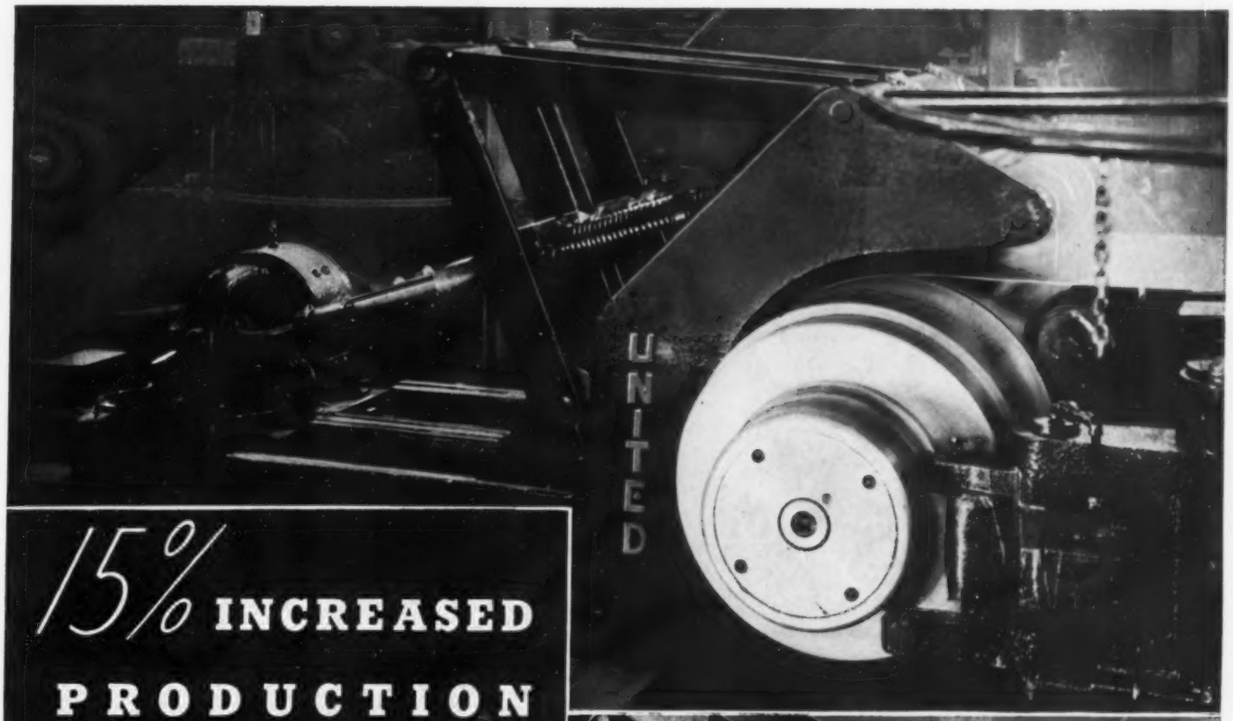

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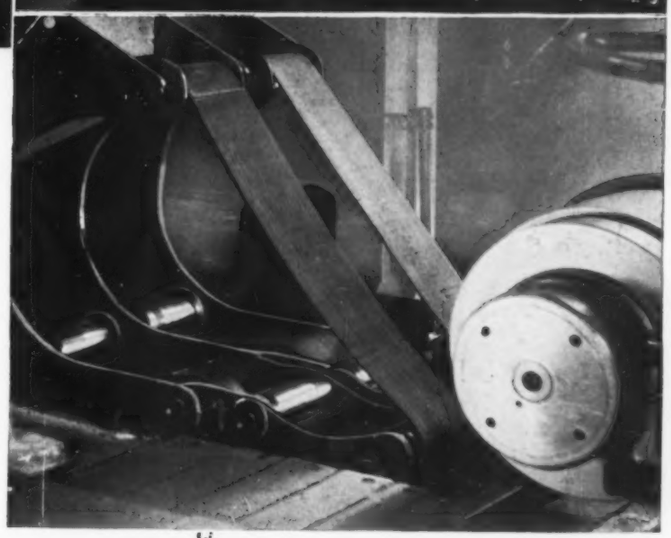

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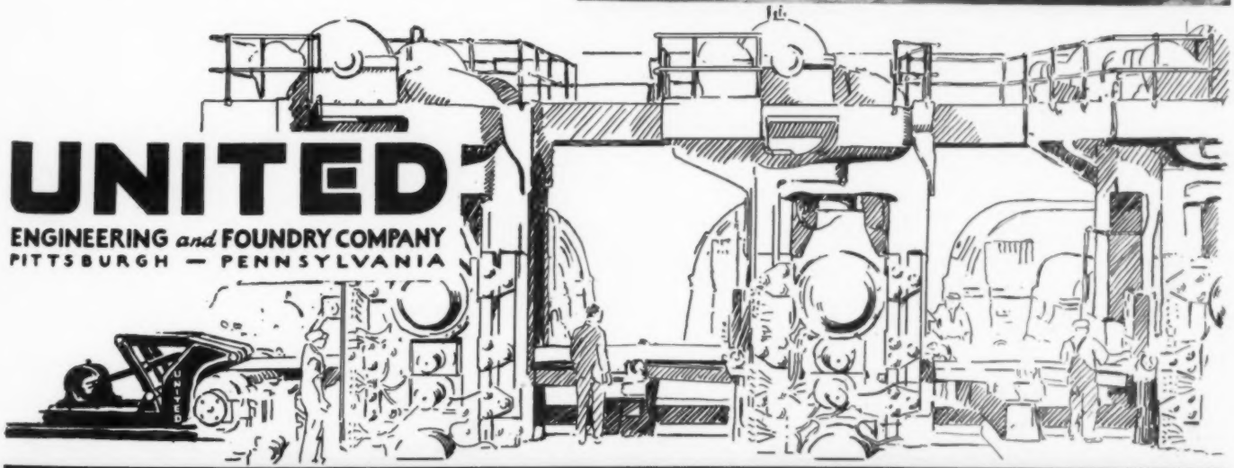

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LOUIS MOSES

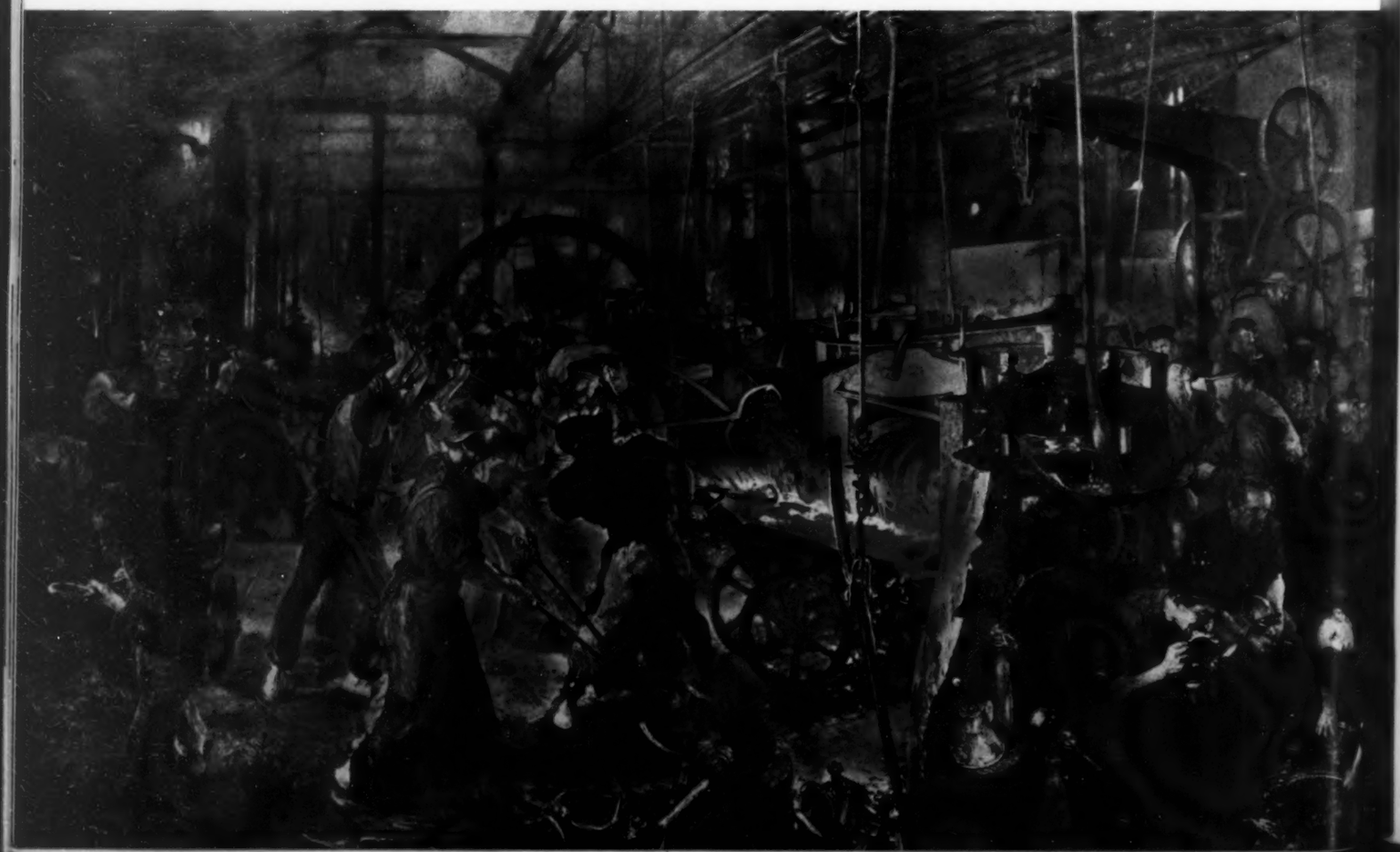
THE *Flow*

▲ THE subject of the evening is of vital importance to the manufacture of steel products. The time alloted for its discussion is inadequate to treat its many highly complex features with any degree of thoroughness. Our discussion must therefore be limited to the more outstanding principles of metal flow between rolls and its regulation. Many details which are in themselves worthy of elaboration will necessarily be omitted.

Roll pass design will not be discussed except as it occurs incidentally in describing flow. The examples and illustrations to be chosen are general and suited for the purpose. They are not descriptive of any Company's methods nor are they peculiar to any operating unit.

Much research will be expended before all that actually occurs between the rolled bar and the roll face is known with a degree of thoroughness rating scientific application. Granting that this is possible with the

While the lower illustration is not indicative of the period the author is covering in his very comprehensive paper, it does afford an opportunity to bring sharply to the reader's attention, the marvelous strides which have been made in the art of rolling steel. This picture is a reproduction of a colored masterpiece by Menzel shown through the courtesy of Professor W. Trinks, head of the Mechanical Engineering Department, Carnegie Institute of Technology, Pittsburgh, Pa.



Flow of METAL BETWEEN ROLLS

By LOUIS MOSES, Supt.

Rail Mill and Roll Department

BETHLEHEM STEEL COMPANY

SPARROWS POINT, MARYLAND

Presented before the A. I. & S. E. Philadelphia Section, January 8, 1938

flats and simple sections the problems assume greater proportions when attempting to formulate exacting principles as applied to compound shapes and sections. The many varying diameters, curves and angles making up groove profiles, all of which are simultaneously working on the rolled bar, set up many variables with very few constants to offset them.

The rolling of steel and design of rolls for that purpose embraces an art pure and simple and is not based upon a science as we understand the term. Mills which are entirely foreign and unrelated to each other will obtain equally successful results by employing widely different rolling schemes.

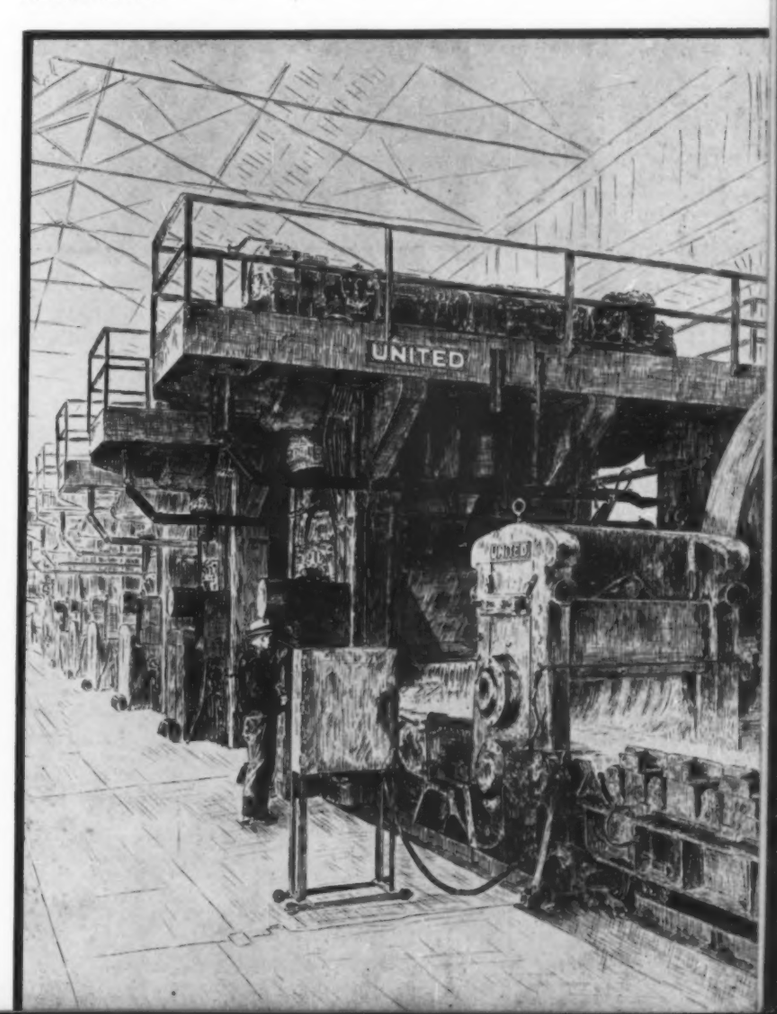
It is almost prohibitive to adapt a mill into a laboratory for the purpose of gathering basic data, even for a short time. Nevertheless it becomes necessary at times to demonstrate something not previously tried out and at such times everyone concerned reads the menu at hand from the right to the left.

Flow is exhibited by a stalled cobble which in one piece displays the form of the entering shape and that as produced by the roll, the curvature of the latter defining the evolution of the one to the other. Although such a stalled cobble provides a means for analysis it is not safe to blindly follow the flow of metal so displayed. Such cobbles are produced at a very low speed or just as the revolving rolls come to a stop. The velocity of the forces causing bar deformation has a most decided influence on the rate and the direction of flow. In smaller mills cobbles are comparatively easy to obtain as produced under actual working conditions. It becomes physically more difficult, as well as expensive, to deliberately make a cobble on the large mills. Roll designers are always on the look-out for unscheduled cobbles and conditions will arise which are capable of analysis only by the use of cobbles.

Steels fall into two main divisions during rolling, with the structure of the initial ingot differing materially from that of the secondary class known as semi-finished steel.

Selective freezing produces a system of finger-like or columnar appearing prisms, whose long dimensions are arranged perpendicularly with relation to the ingot's surface as it cools from a molten state. This structure doubtless persists after heating the ingot in the soaking pit and the surface pattern, as formed by the external terminations of the prisms, constitutes a tender surface

Truly pictorial of the modern art of rolling steel is this illustration of one of the modern continuous strip mills designed and built by the United Engineering and Foundry Company. Metal truly flows between the rolls of these modern mills.



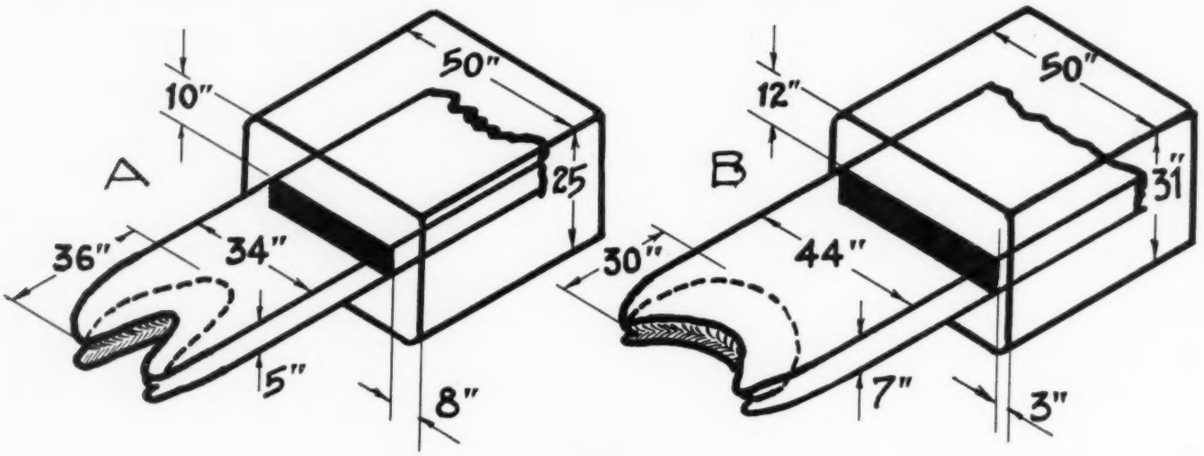


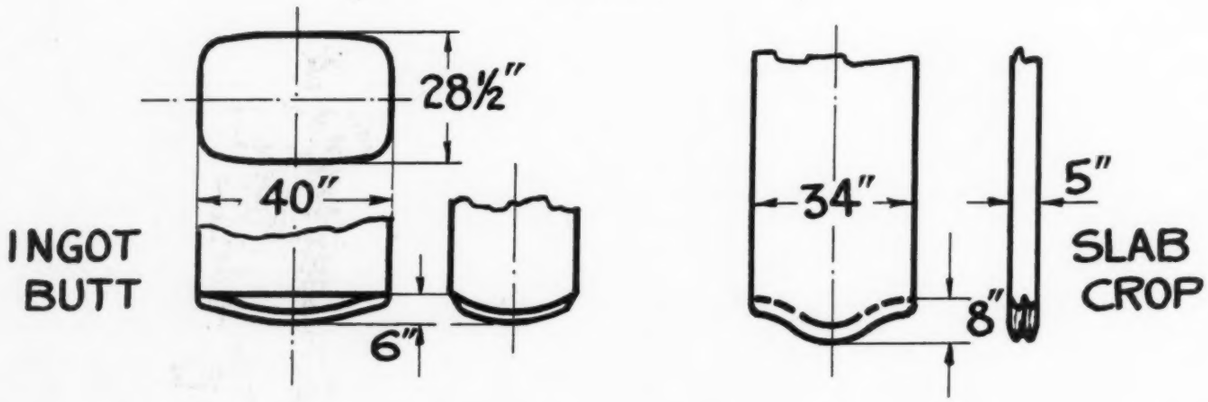
FIGURE 1

which is easily liable to rupture into surface cracks along the lines of the weakest grain boundaries. Because of this condition the first passes employed in reducing an ingot between rolls are relatively light. The surface of our ingot at this initial stage of its reduction is not as plastic, nor amenable to flowing without surface damage, as it will become soon afterward under the influence of properly applied work. Following several relatively light passes on all sides of the ingot the foregoing described skin arrangement is broken down and rearranged into another structure which runs parallel to the surface and conforms to the direction of rolling. In this state the surface metal, or skin, becomes more plastic and malleable than it was in the cast state and is of itself strong enough to resist any surface cracking under the subsequently taken heavier passes. We might compare this to an ordinary steel casting which, because of its similar coarse structure, will not permit itself to be easily forged.

The work performed upon the large and thick mass of metal has tended to elongate the surface zones and very little, if any, stretching has been induced into the interior. While the horizontal faces are being worked upon by the rolls the vertical sides of the ingot undergo visual disturbance, scale is broken and some movement, greatest near the rolls and nil at the center, can be noted.

Rolling and forging cannot be accurately likened to a kneading process. Kneading would submerge portions of the original surface and expose parts of the interior. However, one phase of such a comparison would hold true inasmuch as certain zones of the rolled piece will elongate and spread to the exclusion of others.

FIGURE 2



By such action the respective particles making up the whole are worked upon, either directly or dragged along with those parts undergoing the greatest deformation. Elongation which might otherwise be the result is limited by reason of the reacting and resisting particles to which rolling pressures are not directly applied by penetration. It must be remembered that steel, at rolling temperatures, while it is plastic, nevertheless has a considerable and definite tensile strength and the more or less static interior, by a reacting pull, works the material just as definitely as do those forces tending to directly elongate. It is by these means that the working of steel between rolls confers increased tensile strength, density to the extent of closing up internal cavities, and in varying degrees ductility, as compared with such properties possessed by the cast metal. In a non-academic sense the material of itself cannot be compressed but its particles are brought into more intimate contact with each other. The walls of internal cavities if any such are present, will follow the one certain law of deformation by flowing into the path of least resistance and fill any such openings.

For given purposes we find that ingots are selected whose size and weight are arranged to suit the product to be rolled. Economic and practical considerations, and in some cases metallurgical limitations, do not allow for a complete application of this and the mould sizes of any individual plant become more or less standardized to meet the major line of products. The best practice is to apply as nearly equal work to all sides of the semi-finished product as is possible. The result of this is to use nearly square ingots from which to roll square blooms and oblong shaped ingots in a considerable variety of sizes to make slabs. The use of circular ingots to replace nearly square ones is increasing. It is found that the cooling strains on the surface of a circular ingot are thereby more uniformly distributed as compared to a rectangular one. This application so far is confined largely to the alloy steels and the objective is to produce the finest possible surface to the finished product.

Two different sized slabs as they were rolled from relatively different dimensioned slab ingots are shown on Figure 1. These ingots were cast with straight and flat bottoms. The crop ends indicate where the flow has been greatest by the relative horn lengths of the fishtail. The horns produced with sixteen inches total width reduction at A, are longer than those occuring with six inches of side work as at B. We note that the effects of the rolling pressure are more pronounced at the edges with lessened similar effects at the center line and interior of the slab. These ends were mostly formed when the partially rolled ingot could still be described as being a large mass. It will be remembered that the work applied to large masses tends to elongate the surface. Similar rolling pressures exerted on thinner sections will penetrate into the interior and produce rounded, instead of overlapping, ends as will be described later on.

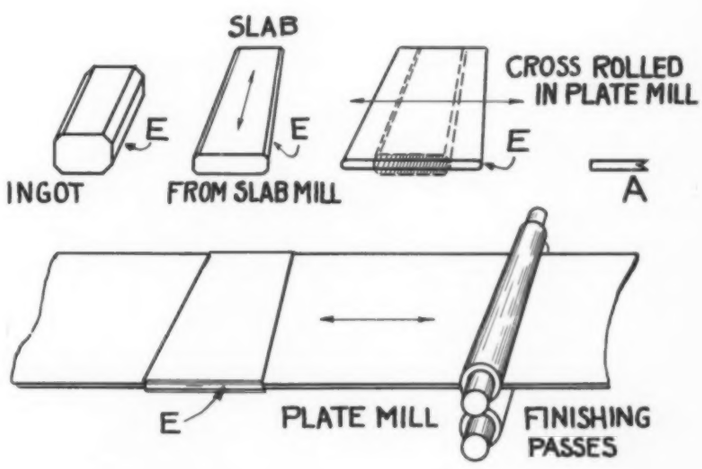
The effect of applied edge work is also noted when reducing a wider slab than is necessary for a given width of finished plate on a universal plate mill. An order for a limited number of plates will sometimes be rolled from the nearest applicable sized slab of the required grade which is at hand. The reduction of a 56″ x 16″ slab into a 50″ x ¾″ plate developed horns which were almost four feet long.

Figure 2 is a scaled sketch showing the form of an ingot butt as made in a specially shaped stool. The swell prevented the formation of fishtails and deep end overlapps by initially supplying enough metal at strategic locations to fill the portions which otherwise would be vacant.

In some grades of steel the flanging operation will display a grain arrangement existing in the plate which runs in one direction only. A straight rolled, as distinguished from a cross rolled plate will sometimes crack at the flanged corner. This will often be found to occur across that axis laying transversely to the direction in which the plate was rolled. For some operations and grade requirements, cross-rolling will correct this condition because in cross-rolling the elongations of the individual grains are equalized instead of being all in one direction. Hot pack tin-plate and sheets, as rolled from sheet bar, are other examples of this. However, it must not be inferred that it is possible to produce a rolled product by ordinary methods of rolling which will possess identical structural characteristics and physical properties in every direction.

Figure No. 3 illustrates the main feature employed in the rolling of exceptionally large and thick plates. The total weight of these required a very heavy ingot which could not be cast wide enough to make the plate width even if such practice would have been desired. The resultant cross section of the ingot, and the slab as made therefrom, necessitated more than ordinary precautions in practice to prevent the formation of deeply overlapped edges. This was required not only from the standpoint of obtaining an economical yield but was also a matter of actually producing the pattern. The ingot was cast with bevelled corners, as at "E", and the slabbing mill rolling so arranged that such corners were maintained and worked upon by the rolls. When the slab was entered cross-wise into the plate mill rolls both the front and back ends were produced

FIGURE 3



into a rounded pattern. When again turned at right angles, after the required width was attained by elongation, these rounded ends became the edges of the finished plate. The arrows indicate the directions of rolling. Had this treatment not been accorded the resulting edge of the half-finished plate, when it was at the thickness where it was cross-rolled, would have been somewhat as shown at "A" and the same kind of an overlapped edge produced in the finished plate.

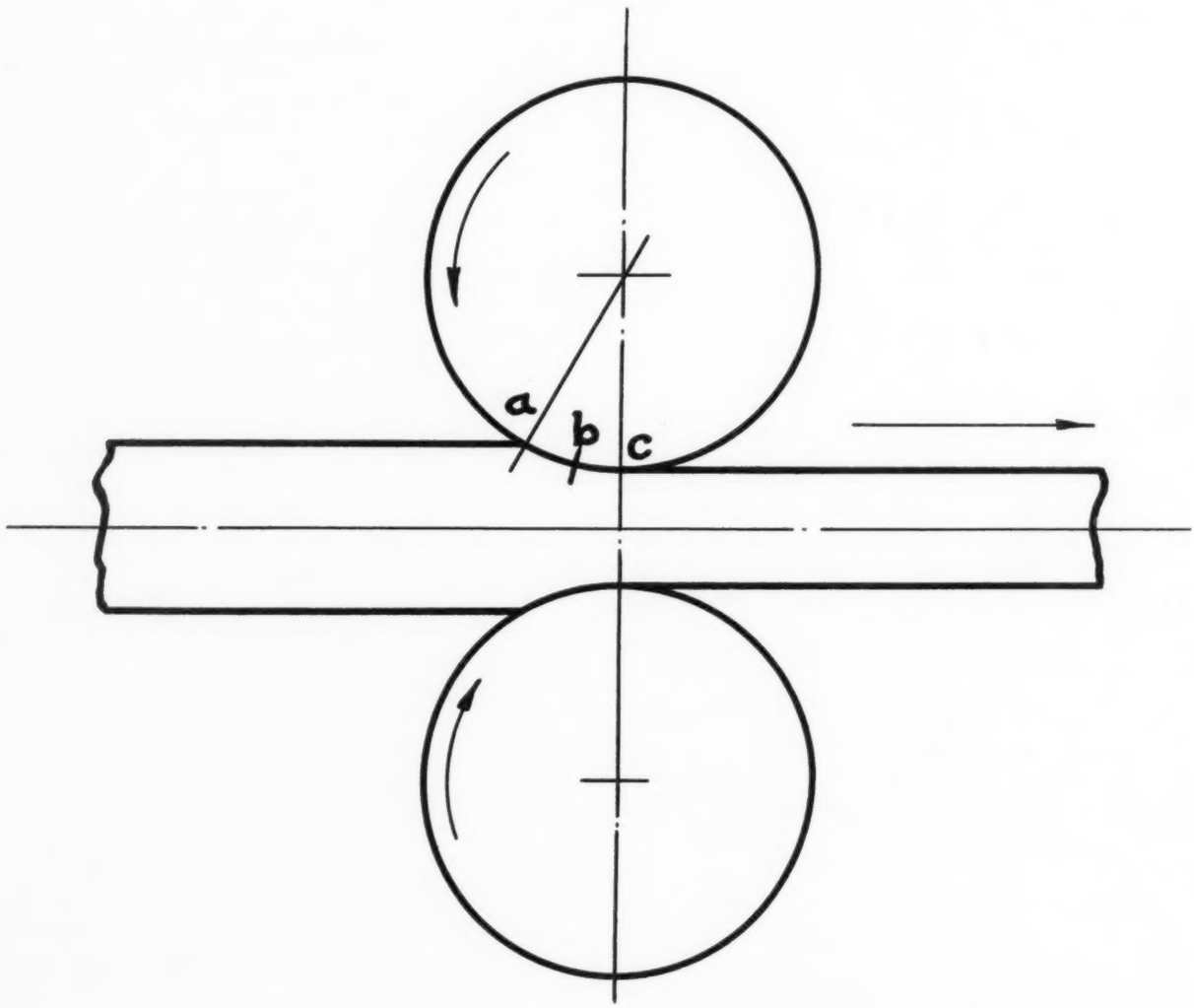
Without the bevelling of corners feature this same method is used in plate mills to effect cross rolling and also to produce widths.

Plate mills which are not served with blooming or slabbing mills must roll direct from a cast ingot. Such ingots are usually made with a decided edge swell, similar to the rounded edge "E" of the illustration, and for the same purpose of avoiding overlapps.

It has been mentioned that very little is actually known of occurrences between the roll face and the rolled bar. Figure No. 4 shows a bar being rolled between a pair of plain rolls. The moving roll faces have taken hold and have imparted a forward motion to the bar as well as reducing its cross-sectional area and elongating it. By observation it is known that the entering speed of the bar is slower and the delivery speed is faster than the roll surface speed. The difference between these and the roll surface speed is affected by many conditions making it a difficult matter to formulate rules of conduct.

Somewhere between the contact arc "a" to "c" a point exists where the speeds of both coincide. Arbitrarily selecting location "b" as being this neutral point it is deduced that the metal between "a" and "b" is being pulled downward and pulled forward. The metal between "b" and "c" is also being pulled forward, or pushed if that is the proper term, as in extrusion, and as it were, squirted out between the rolls. This is not a purely extruding action, however, because the rolls are in motion. The relative buildups of the respective

FIGURE 4



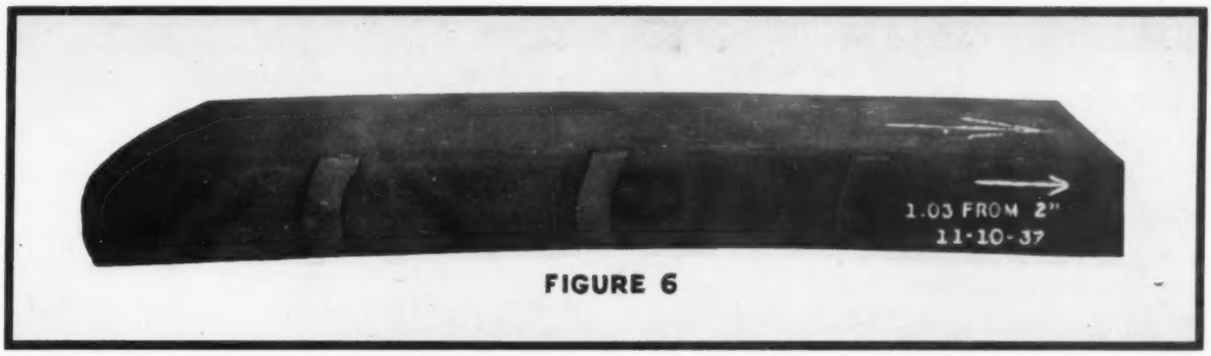


FIGURE 6

slippages probably counteract each other to some extent but two separate states of friction exist, one being caused by the roll moving faster than the bar, and the other through the bar travelling faster than the roll. If no other reasons could be found this alone explains why roll surfaces suffer abrasion.

To cite a few of the variables encountered when studying such phases of rolling action, attention is directed to the manner in which steels produced by differing refining processes, as Bessemer and Open Hearth steels, will react with variable effects under otherwise identical mill conditions. They are likewise noted in the rolling of high and low carbon and with rimmed and killed steels. Temperature of the bar being rolled is of great importance because very widely varying flows are occasioned with relatively hot and cold steel when rolled in the same pass and roll setting. The roll sizes and speeds have marked influences. Modifications when applied in the same amount and to the same character of work will produce differing results. The kind of roll material, the physical condition of the roll faces or grooves and the amount, as well as method, of applying cooling water to the rolls create noticeable diversifications.

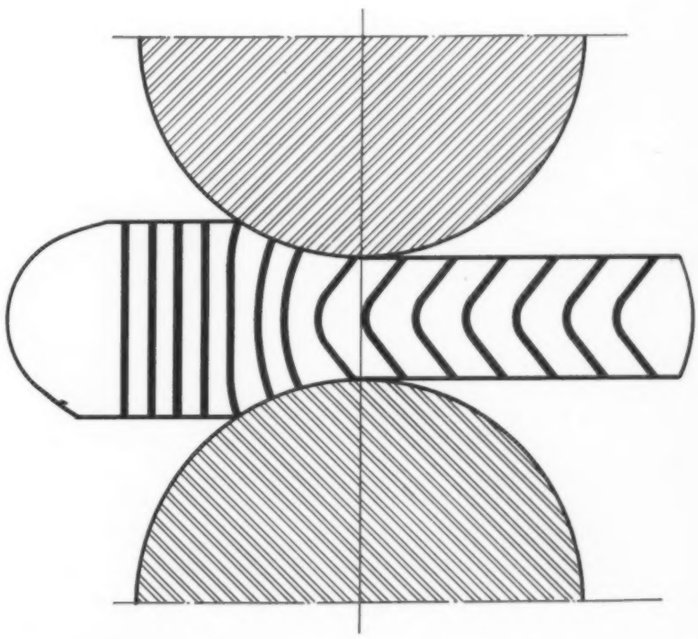
As based upon a number of measurements and timing of delivery speeds the following very general rule can be applied for delivery speeds of plain rolls or open grooved rolls. Within a range of 10% to 35% reduction in area, corresponding to elongations of 1.11 to 1.54, a graduated percentage of 92% to 78% is applied to the product of the roll surface speed by the rate of elongation, to obtain the delivery speed. The entering speed can be worked back from the respective areas. However, this rule may not be applied in such instances as die rolling where a definitely fixed length, or its multiples, must be produced. It is safe enough to apply it with some accuracy to the fixation of mill delivery speeds where the error is frequently made by using the roll surface speed, which is too low and does not consider elongation, or by taking the surface speed and adding the elongation, which is too high.

Not neglecting the fact that the bar is being forced to take a forward motion we might attempt to visualize the flow as it would be revealed by a stroboscope under an X-Ray application to the interior. The particles nearest to the roll face, and in contact with it are disturbed in greater degree than are the underlying particles. These surface zones tend to be forced out between the rolls at a faster rate than the core material, the latter being pulled along with the surface metal. But the interior zones still remain anchored to the unrolled end of the bar and possessing considerable tenacity set up counteracting pulls to the forward movement of the surface zones. Figure No. 5 is adapted from Harbord & Hall and shows the direction of flow in a bar which, prior to its heating and rolling, had tightly fitting pins of the same material inserted therein. After rolling the bar it was cut open through the line of pins, exposing them as being bent about as shown.

To verify this action Figure No. 6 is a reproduction of a photograph showing the etched surface of a bar which was similarly treated, the same action of the direction of flow being clearly indicated by the bending of the inserted pins.

Indicative of the plasticity of steel we note the effects when a regulation .505″ diameter test piece is heated to nearly rolling temperature and pulled. As opposed to the familiar lines taken by the ruptured ends of cold

FIGURE 5



specimens a hot pulled test resulted in the ends being drawn to a shape very similar to that of the business end of a shell projectile, minus its fuse cap. An elongation of over 80% and an area reduction of over 90% was secured. Despite the fact that steels at rolling temperature possess such plasticity the amount and kind of work performed between rolls can be overdone. There are some grades of steel which are intentionally made for certain purposes and which verge on the hot short side when rolled under identical conditions with that of plain carbon grades. Such steels create still another variable to those mentioned before.

The point to be made is concisely stated by a master in the industry when he says that just so much work can be applied which will tend to pull the particles apart but we dare not go beyond the point where the same displaced particles will not unite in their changed positions.

Thus far we have noted rolling operations only from the viewpoint of elongation. It is no less important to consider what is happening to the cross section of the rolled bar. Here we find that certain portions of the material will flow sideways rather than wholly into length, seeking the path of least resistance.

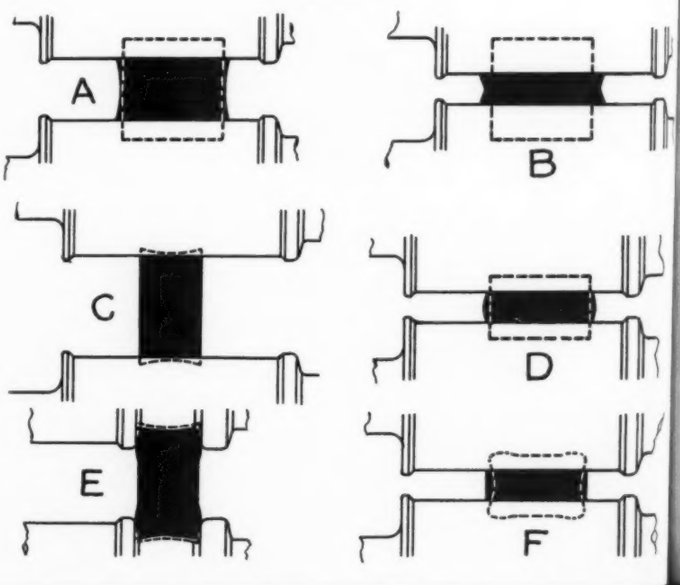
Figure No. 7 shows sectional views of partially rolled ingots. "A" represents a section of about 20 inches square which has been brought to such a size from a larger ingot. Ordinary grades of steel permit rolling this section down to a thickness of about 12 inches without the necessity of turning it. At 12 inches a decided concavity will have been developed at the edges. It will be noted that lessened amounts of rolling pressures are exerted at the core, causing the surfaces to spread more than at the center line of the section. Now, should we continue to roll in the same direction until the piece became six inches thick the impetus given to an overlapped edge would rapidly advance and a decided overlap, or creased edge result as at "B". The edge terminations thus produced would chill and at a lower temperature than the main part of the mass would have a different rate of elongation, causing, very probably, a saw toothed cracking.

To prevent this and to get the structure uniform in all parts, at the edges as well as in the main portion, it is turned up and an edging pass taken as at "C". Now, with the edge squared, if our bar of twelve inches thick would be rolled down to six inches a convex, or swelled edge, would be produced as at "D". This would be due to the penetration of rolling pressures into the core. The thinner section allowed this and the core, by this time being the hottest part and perhaps somewhat softer than the surfaces, would respond to the applied pressures. Because it is ordinarily difficult to hold the bar in a vertical position as at "C" a groove is usually proided as at "E", the walls holding the bar in the desired vertical position without allowing it to be tipped. A further advantage is taken in such instances and a convex surface, or bead, introduced at the bottoms of the grooves so that later reductions in thickness will produce a straight sided edge as at "F".

We thus note that metal flow between rolls consists of two components, elongation and spread, with the greatest effect to the bar produced through elongation. Figure No. 8 shows an assumed case where a bar is being worked between a pair of rolls and shown both in plan and elevation. Assuming the entering section to measure 4″ x .375″ a measured draft of 30% is taken which amounts to .112″ reduction in thickness. If no spread occurred the bar would be delivered at 4″ x .263″, a corresponding area of 1.052 square inches, a reduction of area of 30% and with a ratio of elongation of 1.426%. However, a spread does take place amounting to, let us say, 25% of the measured draft. The bar is delivered at the same thickness of .263″ but with a width of 4.028″, area 1.059 square inches, reduction of area 29.40% and at an elongation of 1.411%. The differential is thus nearly one half of one percent in area reduction and one and one-half percent less in elongation.

We explain spread as being due to the bar seeking escape in the direction of least resistance. Within limits of the total width spread manifests itself at every point across the section with the respective increments being greater at the edges than at the middle. Perhaps this can be made clearer by Figure No. 9 which is necessarily shown to an exaggerated scale and divided into five ordinates at one side of the center line. The friction between the bar and the roll, as measured

FIGURE 7



across from "E" to "B" prevents ordinate "A" from spreading more than is indicated by a^1. The face friction "E" to "C" is less in amount and thus ordinate "B" may spread to amount b^1, which is greater than a^1. In any number of ordinates this action is cumulatively greater as the edge is approached and the summation of all of them is the total amount of spread induced.

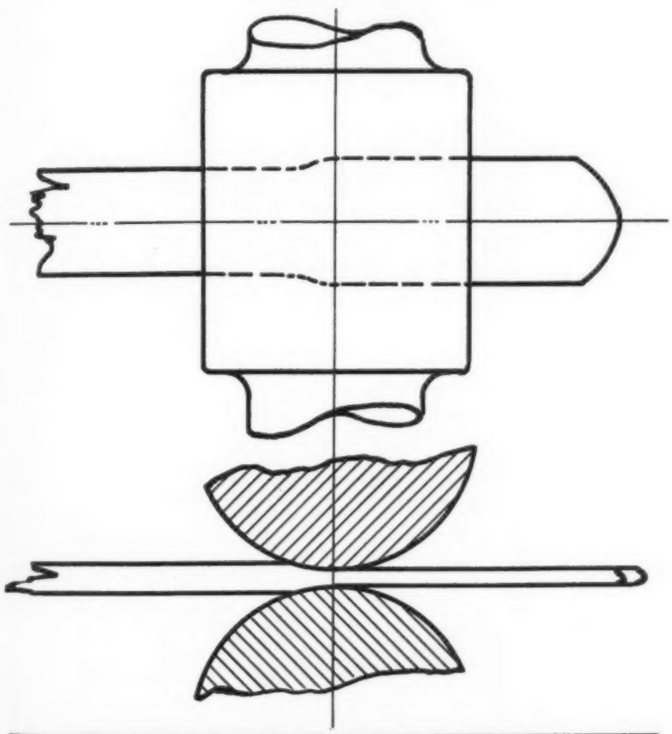
This also explains the generally noted shape assumed by the crop ends which are rounded somewhat as shown. The center ordinates not being permitted to spread the same as at the edges have induced slightly more elongation to the bar than at the edges.

Actually the amount of spread as shown for e^1 is very small although relatively greater than at the other lettered ordinates. We generally count on spread with such methods of rolling on widths up to 15″ or 16″, above which no appreciable spread is noted. At such widths the roll face friction is many times that of the 4″ piece discussed. The total resistance is the product of the arc of contact times the width or bar with the result that a balance is struck at about those widths as named where spread is practically nil in amount.

We shall note a few examples of means taken to limit, to control and to induce spread. These are necessarily limited to the scope of this discussion and are the most simple ones.

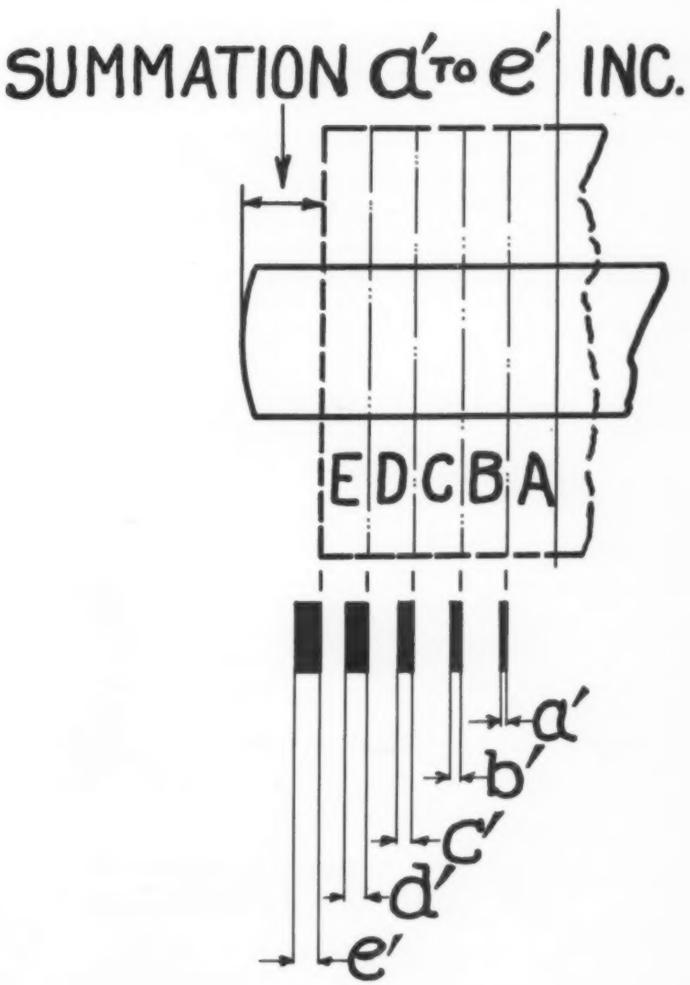
A number of different mills will produce an identical shape but each one will use a different sized bloom, billet or slab because the physical layouts of the respective units allow for certain advantages, or otherwise, as the case may be. Probably spread in itself causes the greatest trouble in cases where it is not possible to obtain a suitable sized blank with which to start. An overwidth, or perhaps an excessively thick, blank will result in excess widths. In other cases it might be necessary to use up underwidth blanks and spread must be induced. In all cases an accurate and definite

FIGURE 8



SPREAD	AREA	RED.	ELON.
IF NONE	1.052	30%	1.426
ASSUMED @ 25%	1.059	29.4%	1.411

FIGURE 9



control must be secured throughout the system of passes.

Figure No. 10 shows four passes but the application is extended to any number with sufficient edging work intervening between the reducing passes. A bar of suitable size has been selected and passed through passes Nos. 1 and 2. The reductions in thickness spread the bar and to produce the desired finished width, and to heal the edges, the bar must be edged. Either in a vertically or horizontally arranged edging pass the bar is edged back to a width somewhat narrower than the finished section out of No. 4 pass. The amount required for this purpose is dependent upon the draft taken in No. 4.

Figure No. 11 shows a variation of the same scheme. Here the walls of the grooves limit spreading but do not entirely prevent it. This type of groove is desirable where fluctuating temperatures are likely to be met with, the extra spreading of cold bars and ends being checked. A further advantage is obtained through the alternate working of the corners and part of the edges. In this wise the walls of the grooves exert counteracting side pressures to the spread.

The treatment accorded to a 3 inch square billet as shown on Figure No. 12 is decidedly not recommended because of the very great distortion and possible damage to the material. Limitation of the amount of work possible to apply has been mentioned. Outlined from cobbles secured during an unsuccessful attempt this scheme was applied to widen an under-width billet but too much latitude was taken and a badly rounded edge, in lieu of the square edge wanted, was produced. It will serve as a horrible example.

The metal in the middle of the bar flowed to the thick edges and these in themselves provided more stock to work on and allowed for the production of an increased amount of spread. While the central throat

FIGUTE 10

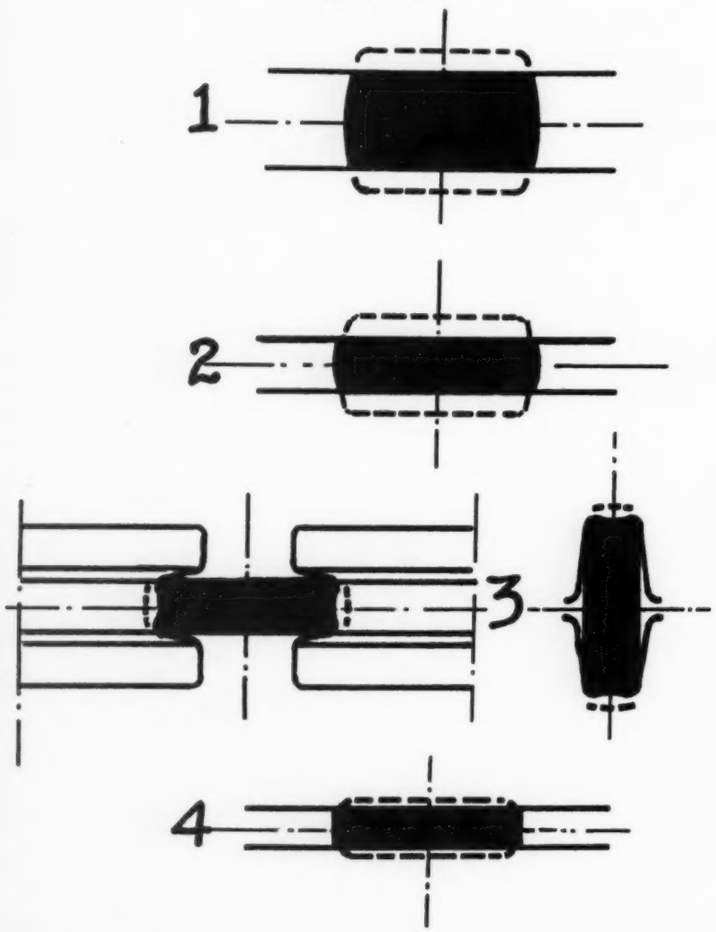
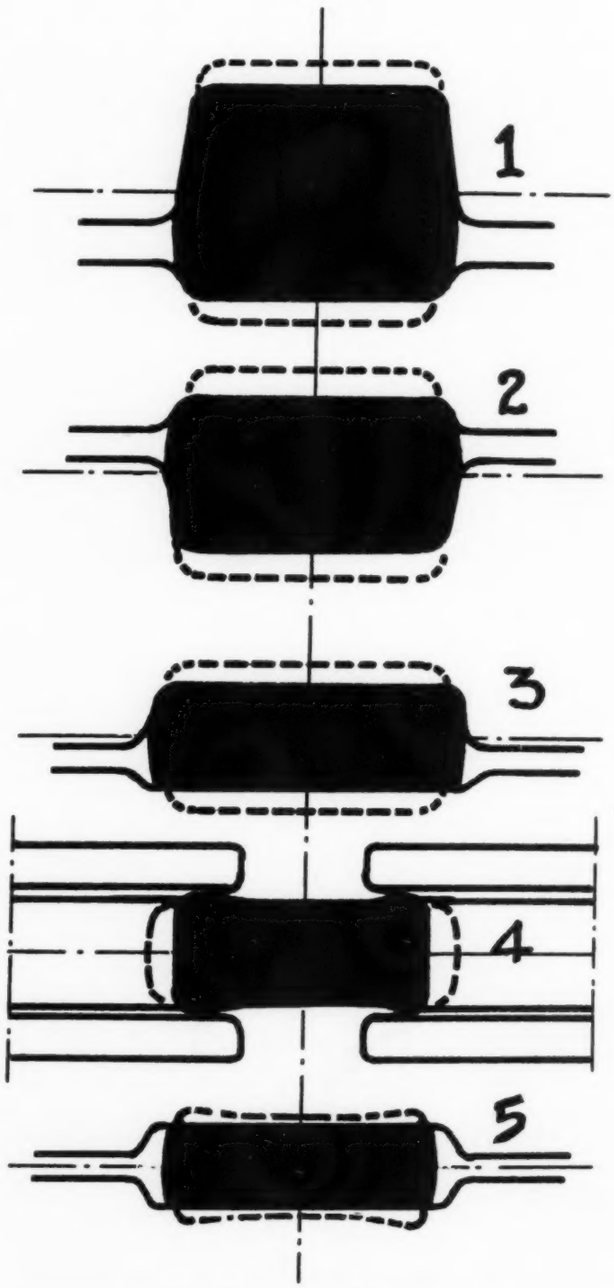


FIGURE 11



thickness reduced the frictional contact between bar and roll face the heavy draft taken produced sufficient friction to make the bar act much the same at the middle ordinates as was previously explained. That there was little, if any, flow toward the center is manifested at the gutter "A". The path of least resistance in this case was elongation and the action carried along the surfaces of the thinnest part. Had the rolls, instead of revolving been two circular faced dies mounted in a press, and a similar amount of work applied, it is very probable that some trace of the gutter would remain. Thick portions of a bar will sometimes act thus by actually pushing adjacent thinner portions to an even more pronounced minus thickness.

In a very much lessened degree of effectiveness, but with added amounts of spread over that secured with straight and parallel rolls the principle is successfully applied by using one crowned roll with its mated roll turned straight. The tapers in such cases are generally not as acute as shown.

Bars up to 12″ wide will spread about 30% of the applied draft in 28″ to 30″ mills. Spread of about 23% will occur to widths 6″ to 8″ in 20″ to 22″ mills. On some kinds of steel spreads of 40% maximum are noted with 5″ to 7″ widths when rolled in a 12″ mill. No actual rules are possible without considering thickness and kinds of material worked on. Small mills offer still greater ramifications with breakdowns, strands and finishing grooves, of regular and irregular shapes, all offering, as one writer puts it, surprising results.

In hands of our highly respected friend the blacksmith we will see the effects to a bar when struck respectively with a sharply rounded fuller tool and the flat face of his sledge. The small radius sinks into and wedges the bar into a longer length in the direction at right angles to the face of the tool and without causing any spread lengthwise to the tool. The blunt face of the sledge spreads the metal across the bar in every direction, dividing the deformation into as much spread as elongation. Similarly, and for identical reasons, small diameter rolls produce elongation with little spread as compared with large diameter rolls under like conditions. Under the same conditions large rolls produce more relative spread.

This phase of the use of relatively small rolls in continuous wide strip mills has received scanty mention in the many descriptions of such units. As an underlying principle of design it receives vital and primary consideration in the calculations of the mill builder. Small rolls are easily broken and without the backing-up rolls the tremendous pressures exerted to the product being rolled could not be applied. There is no known way to make a hard faced roll sufficiently large to withstand such pressures. Even granted that such a feat was possible the rolling itself could not be accomplished because of the wide arc of contact presented to the bar which would create torques beyond the capacity of existing driving motors.

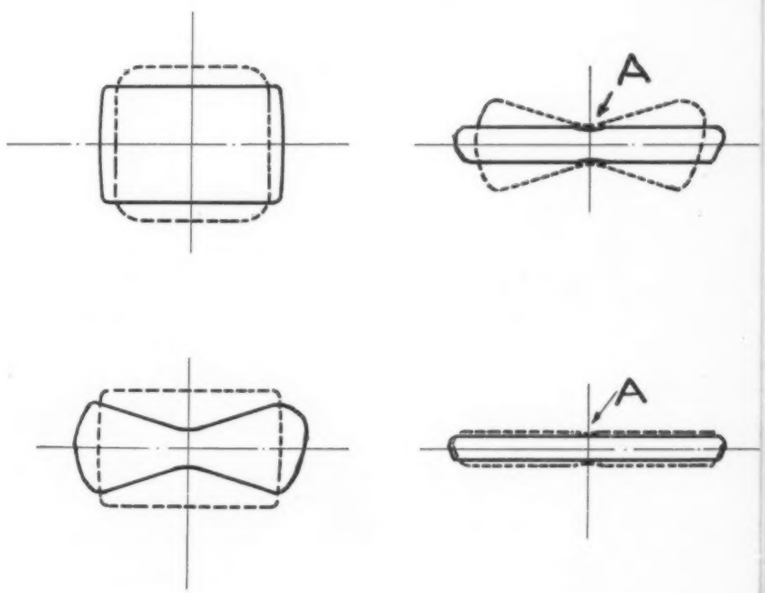
Another example of this lays in the small middle roll of the three-high or Lauth, Plate Mill. There would be a marked increase in the power input of such mills if all three rolls were of a corresponding diameter to the tops and bottoms.

Significant in most plate mills is the pattern assumed by the rolled ends of the plates. End patterns will vary from being a nearly straight line up to, on occasion, a pronounced concaved or fishtail like pattern. The less the length of the outside ends, and the closer to a straight line the end will assume, the closer to parallel will be the gauge across the section.

In wide plate rolling it is thus found that the centers gauge somewhat heavier than at the edges. Roll deflection plays only a limited part in causing this. The condition is present with newly dressed rolls so that, within limits, roll wear is not entirely responsible. Referring to Figure No. 9 we then observed that bars wider than 16″ display little appreciable spread. Little trouble is experienced with gauge variations on bars up to 24″ wide. Compared with these widths we note that wide plate rolling is accompanied by a great many more ordinates and that these multiply the desire of the section to spread sideways between the rolls. At the same time the greater total area of the roll contact arc creates a greater resistance to the occurrence of such spreading. There is therefore an internal compression which must be relieved because steel cannot be compressed. Discounting roll wear and roll deflections the principle requires a more or less detailed explanation.

Assume that one pass only is to be taken and that the entering plate to be reduced in thickness is perfectly straight and square. Entering it between the plate mill rolls and taking a draft the front end, viewed in plan, will emerge straight, the back end will tend to be concave, the middle of the section will gauge heavy and the edges gauge thin. The middle zone tends to run ahead of the edges because it cannot spread and can only go into elongation. The edges try to keep up to the middle. Perhaps because there is some opportunity for the edges to spread a very little they are proportionately robbed in thickness. More likely a

FIGURE 12



drawing action occurs which draws the metal at the edge zones into the direction of the greater pull of the middle-zone elongation and causes this robbing of edge thickness.

The locations of greatest abrasion occurring to the roll faces sometimes lend clues to an analysis of conditions such as we have here. Parallel faced rolls of other mills, making up to 24" wide flats, with little gauge variation, show the greatest wear at the section width edges and very little wear at the center of the roll. After short durations of running Plate Mill rolls will show the greatest wear at the center of the roll face and none whatever at the edges. These rolls, and particularly the friction driven middle roll, are usually turned to a more or less barrel shaped contour and are thus larger in diameter at the center of the roll body than at the ends. Most, if not all, of the roll deflection when it is under load is thus cared for. However, it is primarily done to offset the above noted gauge variations so far as may be possible and not interfere with a practical mill operation. The central contact of the friction driven middle roll with the top or bottom roll has its influence on roll wear, of course. Nevertheless, and before appreciable wear is encountered with newly dressed rolls, the condition is present. Central zone elongation is greatest on wide plates, this induces drag to the edges which do not contact the roll faces with the same pressures because they are at a reduced thickness, and discounting all other conditions this is borne out by roll wear.

There are other kinds of rolling wherein spread is restricted or entirely prevented, in which the same phenomenon occurs.

The layouts on Figure No. 13 are shown in an elementary way and do not represent practical groove construction. They will serve to illustrate a very important aspect of flow which is met with in some kinds of shape rolling. A loss of flange height is always present when working down a thin web from a rectangular bloom and at the same time maintaining the required height "H".

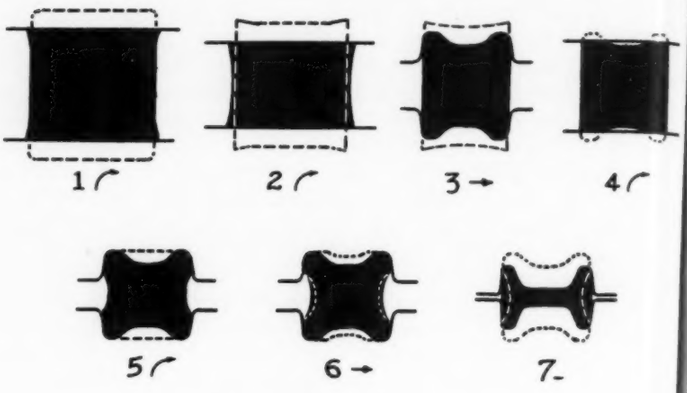


FIGURE 14

As shown by the cross-section through the rolls the larger diameter "W" which works on the web has a higher peripheral speed than the diameter "F" at the flange edge. This larger diameter pushes the metal of the web forward at a faster speed and drags the metal from the flanges. As shown at point "X" the material does not touch the roll at diameter "F".

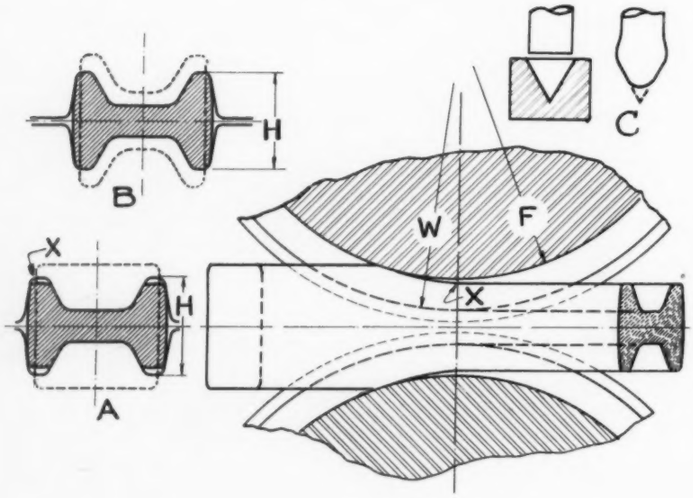
This illustration is illustrative only and also shows a principle used in rolling operations where a previously formed blank shape is used. In such work the flange height of the entering blank is high enough in relation to the web thickness to allow for the loss. This is shown by Figure "B" where the flange height "H" is such as to compensate for the web elongation.

The pulling down, or shortening at the flange terminations may also be likened to forcing a bar into a die, as at "C", and expecting a sharp point to be produced. Regardless of how much downward pressure is applied the metal will draw and the point will be rounded somewhat as at the right hand profile.

Figure No. 14 shows a rolling scheme to produce a shaped bloom in a formerly used method of rolling I beams. A flat ingot groove, a beaded groove and a finishing groove were incorporated in a set of rolls and 23 passes employed. The numbered stages indicate the manipulation in turning the bar from pass to pass, or no turns, as the case may be. A feature to be noted is the spreading action at the middle which would soon overfill the roll collars if not prevented. When on the subject of reducing large rectangles it was noted that the rolling pressures did not penetrate to the horizontal center lines and that little spread occurred at such locations. In cases such as this one the tongues of the rolls are digging deeply and forming grooves in the section, this inducing very considerable spread across the roll partings. The manipulation indicated shows how beads were rolled in the sides to a sufficient amount to prevent such overfilling. These amounts are shown somewhat in exaggeration.

Mention of I beam sections suggests that a description of the outstanding features in rolling methods used in such work is also illustrative and pertinent to our

FIGURE 13



subject. Referring to Figure No. 15 it is seen that the component portions of the whole section must be considered from two standpoints. The physical formation and working of the flanges must be thought of as if each was a separate entity in itself but along with this the areas produced must also be considered in relation to the total work done on the section as a whole. For instance it might be under consideration to reduce the flange areas to an amount of 10% along with a 15% reduction to the web. The result of this would be to elongate the web more than the flanges but the flanges would resist the web going out the extra 5%. The work would be performed on the webs, nevertheless, and the section would have a wavy, wash-board like web. The flanges and the web must be produced and with as near a similar amount of work to each as is possible to achieve.

This is accomplished about as shown at the line of passes numbered 1, 2 and 3. It must first be noted that each pass has its open and its closed sides, as indicated by the roll collars. Starting with No. 3 the closed bottom flange openings, sunk into the roll integral with the groove sides and all in one roll, cannot perform any side work to reduce a flange thickness but they can edge back metal in a vertical direction. The top flange opening is not in one roll but is made up of the two rolls. The speeds of the respective inside and outside faces are at variance with one another with the bottom roll collar speed faster than the top roll tongue speed. Therefore, we have an opening, similar in working respect to a die and anvil, between which side work can be performed. As will be seen at "C", and also at the cross-sectional view of the rolls, the flange of the outside is worked against (in this instance) a 34" diameter collar and on the inside, or tapered part of the flange, against a 22" diameter.

Using three passes to illustrate layouts which will actually total from 9 to 13 passes we find No. 2 pass has its open and closed sides respectively reversed from No. 3 pass. In this pass the bar as it comes from No. 1 pass is worked in the same way by reducing flange heights in a vertical direction in closed holes and side working the opposite pair of flanges between the open side of the pass.

An attempt is made to show this alternately performed work by lettered dimensions, which in themselves are not exactly literal but are used to convey the idea. Using "h" as the finished flange height the bottom flange of No. 2 pass is made longer but at approximately the same thickness. Again using "h" as a unit value the closed top flange No. 2 pass is made the same length but is thicker by the amount measured by "t" plus. A, B and C show the respective flanges as though separated and not connected by the web. The heavily shaded portions show where the work is performed in alternately arranged grooves.

The work on the webs has caused spread as has also the work on the inside faces of the flanges. Some of this is allowed in pass construction but solely from the standpoint of making prior numbered passes narrow enough to enter succeeding ones and to allow for side wear during the life of the roll. Keeping in mind the remarks previously made on tongue work causing spread it is seen that the solid sides of the collars definitely resist more than an allowable amount and work the metal between them.

Another kind of flow is encountered which is the exact reverse of spreading. Figure No. 16 shows four grooves in outlines as used in the rolling of a tapered tie-plate. With the intervening grooves not shown these are selected to illustrate the principle involved. Here the drafting from pass to pass is arranged so that the amount of work is proportionally equal at all of the various thicknesses. As subdivided and lettered at pass No. 3 for convenience the parts, "A", "B" and

FIGURE 15

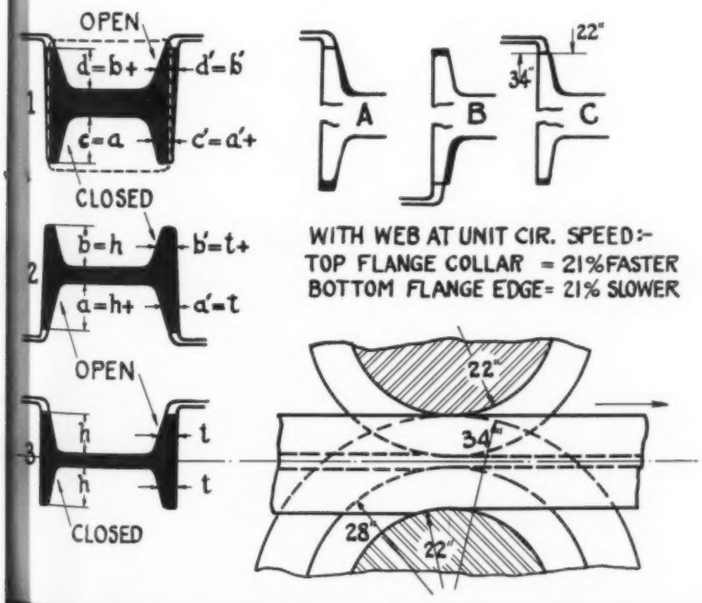
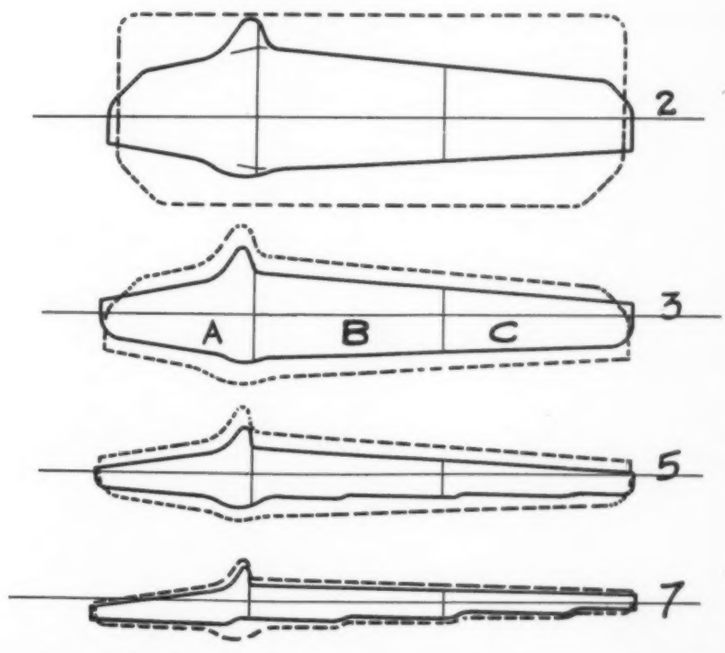


FIGURE 16



"C" each receive the same percentage of area reduction. This results in heavier measured drafts at the thicker parts and lighter drafting, by scale measurement, at the thinner ends.

If the drafting was otherwise arranged and work, as measured in fractional inches, applied equally to all of the parts across the face of the section, the percentage of reduction at such respective parts would vary. In such a manner a ¼ inch reduction would perhaps occur to the thin ends and also to the thick middle causing the percentage of reduction to be greatest at the ends. The thinner parts of this type of section invariably will travel along the often mentioned path of least resistance and flow to the thick center of the bar. Note that the opposing faces of the two rolls form a wedge shaped opening and with such kind of groove construction there would be nothing to induce the metal to flow into the curtailed end dimensions. As stated, the inclination is for it to flow in the opposite direction, or into the thick parts and then into elongation.

By arranging the work as described and as illustrated a resistance is set up to such inward flow and counterbalances it. The ends of the rolled section are thus maintained at their appointed places and overall widths produced to the desired dimensions. This type of pass construction counteracts, to some extent, the temperature variations across the section because the thin ends cool more rapidly than the thick centers.

Schemes of rolling, such as are used in rod mills, depend upon means to rapidly produce a maximum elongation to the rolled bar. The types of passes employed are about as shown on Figure No. 17. These are known as open passes. A is a breakdown oval into which a square is being entered. The produced oval is then turned up and entered into an open square as at B. These are always considered in pairs. C illustrates a breakdown oval entered into a round groove, the latter, in this case, taking the place of a square and not to be considered as a finishing groove for a round section.

A square bar entering an oval has the spread retarded by the walls of the oval groove and some of the metal tends to flow inward into the thickest part.

Similarly, the entering oval into either a square or a round will flow the metal into elongation.

Passes D, E and F show a breakdown scheme for rolling billets, these employing the same principle but maintaining corners.

An interesting example of the effects which varied temperatures have on a bar undergoing rolling is shown by Figure No. 18. Here a shouldered tie-plate was rolled with the transverse lugs formed in one finishing pass. The sketch to the right, at a larger scale, shows the general shape of the section. The multiple length "P" was aimed at but in a rolled length of seventy feet the variations from end to end were about as shown by the tabulation. The plus amounts at the front end, as compared with the minus amounts at the back end, are the result of varied temperatures. A difference of probably 50 degrees would be looked for to produce this effect. The hotter front end lends itself more readily to extrusion, and slippage in a forward direction between the rolls, than does the colder back end.

Figure No. 19 shows another manifestation of the effects of temperature difference. The shaded part of the bar, as shown in its rolling position, is the hottest. This hotter part, as in the case of the tie plate, lends itself to being extruded more than the colder opposite side and the bar bends at a long radius on the hot side and a short radius on the colder side. Figure No. 20 is intended to show a flat, in plan, with the same effect and for precisely the same reasons.

The effects and kind of flow encountered in the rolling of the smaller sections is not touched upon here. Looking over the published handbooks of such products we can wonder how they are produced in such variety

FIGURE 17

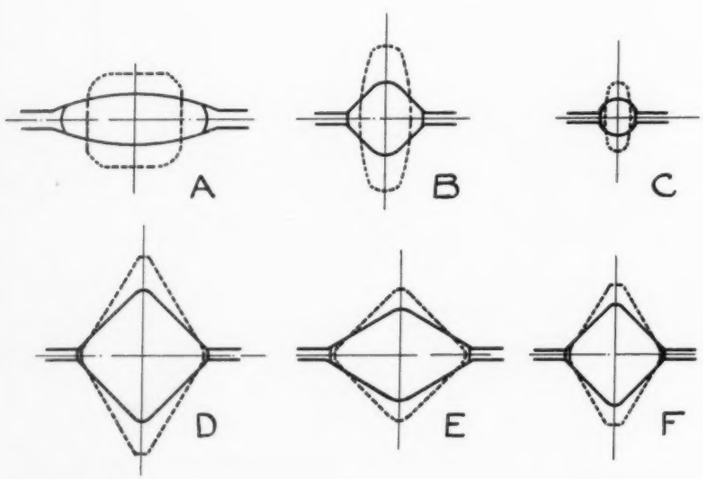
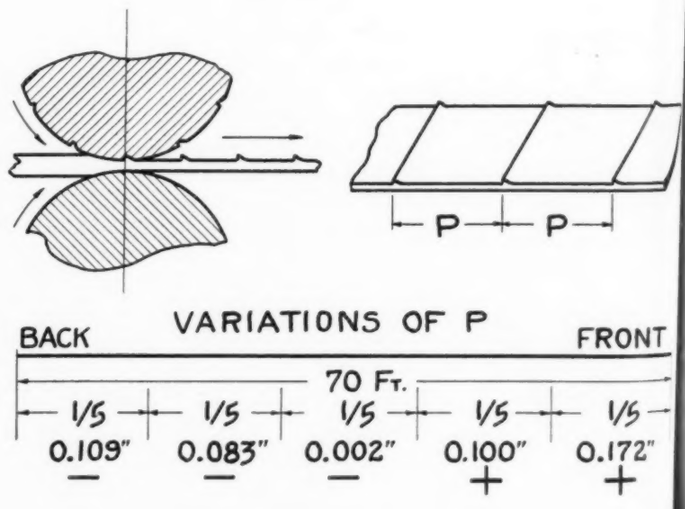


FIGURE 18



without means of extrusion between dies or a drawing process. In a general way the foregoing remarks are applicable to small section rolling but the means employed vary widely. This constitutes a field in itself. Many other rolling schemes could be shown but all of them have the common aim of inducing the most rapid reduction in area and maximum of elongation, or the quickest evolution from blank to shape, as is consistent with the kind of material being worked upon.

Rolling mills designed for the production of a limited number of products in great volume predominate over the older installations which roll a wide variety but at lower production rates and higher costs. At least this has been the trend. The older mills provide a field for the exercise of pass design and rolling schemes which is mostly confined to the roll department and operating organization. The later designed mills make no less demand on the roll man's talents and skill, in fact his ingenuity is sorely tested in arranging for new products to be rolled on such specially designed mills. The transition period between the two types, however, resulted in the mechanical engineer becoming more keenly interested than his predecessors were in this subject. He required more detail so as to best adept the design of the mill and its accessories to the intended volume production. Over the years we can note a demand for a wider dissemination of rolling principles into circles other than the roll departments. In recent years it is receiving, as it should, closer attention from the metalllurgical divisions.

There are a number of interested engineers to whom the subject appealed and who have devoted considerable attention to reducing assembled data into applicable principles which have been published. These works are well worth referring to and as listed are recommended to those interested beyond the scope of this paper.

ROLL PASS DESIGN—W. Trinks, Professor, Mechanical Engineer, Carnegie Institute of Technology.

THE MAKING, SHAPING AND TREATING OF STEEL—J. M. Camp and C. B. Francis, Carnegie-Illinois Steel Company.

THEORY AND PRACTICE OF ROLLING STEEL—Wilhelm Tafel.

THE METALLURGY OF STEEL—Vol. II—Harbord & Hall.

A bibliography published March to June, 1929 by the BLAST FURNACE & STEEL PLANT was very complete at that time and many other articles have appeared since then in the various Trade Journals.

But a perusal of these must be complete to make a successful design of roll passes for a given section. There have been mills built without referring to the skill of a roll designer or mill operator. In such mills, sometimes a detail which was seemingly of no importance to the whole, such as the effects of spread, or the ratio of reductions in a continuous mill, was disregarded with disastrous results that might easily have been avoided.

As I close, I have in mind the jokingly expressed thought of a very noted student and writer on roll design. He once told me "Them which knows don't tell and them which tells don't know". I must now depend upon his, and your, generosity as to which of the two I have shown myself to be.

FIGURE 19

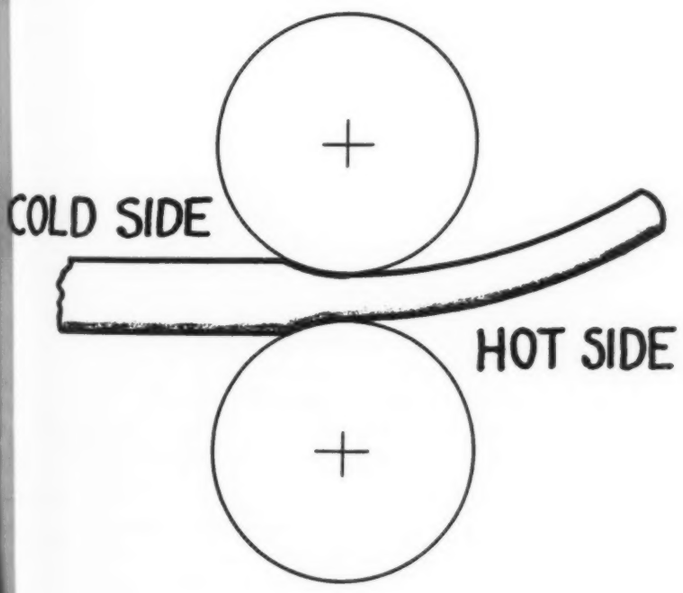
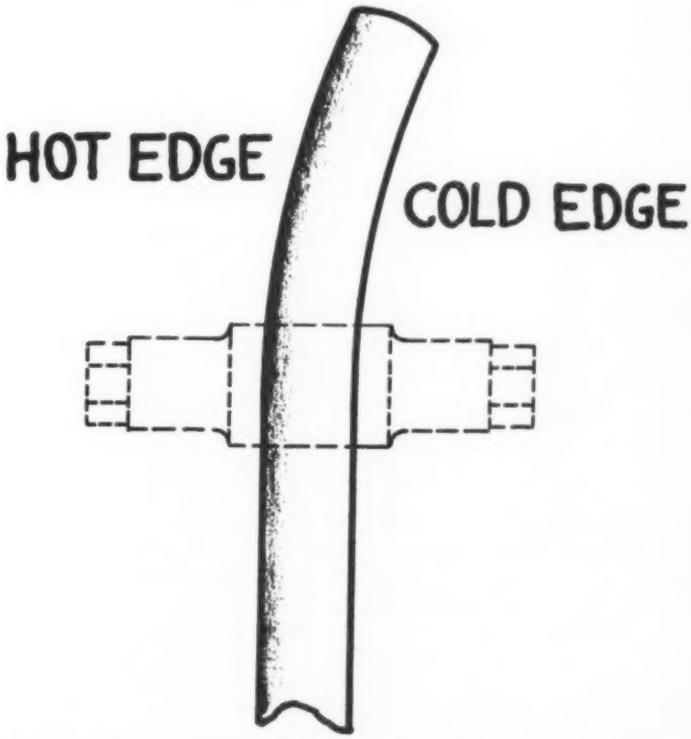


FIGURE 20



DISCUSSION

PRESENTED BY

L. F. McGLINCY, Superintendent Open Hearth and Rolling Mills American Steel and Wire Company, Worcester, Massachusetts.

CHARLES R. PHIPPS, Superintendent Roll Department, Bethlehem Steel Company, Lackawanna, New York.

C. R. HAND, Lubrication Engineer, Bethlehem Steel Company, Sparrows Point, Maryland.

HARRY K. MAXWELL, Superintendent, Roll Department, Bethlehem Steel Company, Bethlehem, Pennsylvania.

C. R. FOX, Superintendent Hot Strip Mill, Bethlehem Steel Company, Sparrows Point, Maryland.

W. E. GRAINGER, Assistant Superintendent, Coke Ovens, Bethlehem Steel Company, Sparrows Point, Maryland.

F. O. SCHNURE, Electrical Superintendent, Bethlehem Steel Company, Sparrows Point, Maryland.

L. F. COFFIN, Superintendent, Mechanical Department, Bethlehem Steel Company, Sparrows Point, Maryland.

GEORGE B. McMEANS, Superintendent, Blooming and Bar Mill, John A. Roebling's Sons Company, Roebling, New Jersey.

W. T. MILLER, Superintendent, Roll Shop, Lehigh Division, Bethlehem Steel Company, Bethlehem, Pennsylvania.

W. PAUL GERHART, Assistant Metallurgist, Bethlehem Steel Company, Sparrows Point, Maryland.

J. R. ADAMS, Special Products Division, Midvale Company, Philadelphia, Pennsylvania.

LOUIS MOSES, Superintendent, Rail Mill and Roll Department, Bethlehem Steel Company, Sparrows Point Maryland.

L. F. McGLINCY: Mr. Moses' talk was very interesting. I am afraid if I begin asking questions I may go into the subject too deeply. However, his discussion touched on high carbon, low carbon, rimmed and killed steels and the question arises in my mind if provision is made in the pass design to compensate for the difference in flowability of each grade of steel. Take a continuous rod mill for instance, is it necessary to make a compromise in the pass design when rolllng a wide variety of steels in the same lineup?

LOUIS MOSES: Well, Mr. McGlincy, your problem is the same as on other rod mills where pass contours and drafting must be compromised to enable the rolling of all grades of steel. Killed steels vary in the amount of spread when compared with rimmed grades, with the latter spreading the most. While it is true that over the years a pass development undergoes compromise and alteration, through trial and error, to roll all of the grades of steel, it is not entirely a matter of roll pass design. I would like to get across that the mill man and his ability must not be neglected in meeting these problems. A good roller can do wonders with a poorly designed system of passes and an inexperienced roller can play hob with an ideal set. A roller instinctively recognizes, in the way steel will flow, the various terms we are using, such as strength at rolling temperatures, the effects of heating otherwise, elongation, spread, etc. In any mill there are daily instances of roll setting adjustments required to produce a good product and which are sometimes slow in getting to the attention of the roll designer.

L. F. McGLINCY: I might ask another question. Do you have any experience rolling the SAE 3135 grade?

LOUIS MOSES: I am not too familiar wtih S.A.E. groupings without having a reference table before me. The grade you mention is probably an alloy steel and I am not any too familiar with the behavior of these. I would think there would be a difference between them and ordinary carbon grades.

L. F. McGLINCY: I realize that when I start asking questions they may become quite involved, but I wanted to get the benefit of your experience if possible on this particular feature as we roll steels from 120 carbon down to 3 carbon, acid, basic and Bessemer varieties and I wondered if our ideas jibed with yours.

LOUIS MOSES: The wide range of carbons you mention along with the various grades otherwise, undoubtedly create conditions of variable flow, one to another. It should be possible to compromise the groove profiles, by trial and error, but none the less largely possible, so as to enable the rolling of all grades in the same passes Mill practice and temperature play their part as well.

L. F. McGLINCY: Of course, these are all continuous mills I am talking about.

LOUIS MOSES: Yes, I understand.

CHARLES R. PHIPPS: Mr. Moses has given a very clear and satisfactory talk on this subject. His observations agree with my experience in this same line of work. I might add, however, that in addition to the spreads he mentions, in other grades of steel the spreads sometimes go much higher, say 40% in some cases, and in others still higher.

When rolling ordinary open hearth steel, of .93 to 1.05 carbon into bumper stock, (spring steel grade), we found, very much to our surprise, some years ago, that the spread in first passes varied from 66% to 100%. The amount of spread in proportion to the draft began at 66% in first pass and reached 100% in the fourth pass. At the seventh pass it was 133%. The remaining three passes were given very light draft. Mr. Moses' paper was on other grades of steel, but I just wanted to state that spread is a very variable factor, much depending on grade of hardness of steel and the rolling speed.

At one time we were rolling tractor tires. These were flat sections with a raised portion of 2″ in width at each edge about ½″ thicker than the main part of bar, which was ⅜″ to ⅝″ in thickness on the different sections. For the 30″ wide section a slab of 34″ x 5″ had to be used; for the 24″ section a slab of 27″ x 5″

and for the 18″ section a slab of 19½″. While there was a pair of verticals in the mill, they were used only to hold the edges somewhere near square. This is a case where there was no spread, the metal all going out through elongation. The mill was a 30″ two-high Plate Mill.

Another observation made was with a 5″ x 5″ bloom, which was reduced in one pass, on a 28″ mill to a 5¼″ x 3½″ bloom. With normal mill speed this reduction made a good bloom, but when the mill was once run at a very slow speed on last half of bar it made an overfill or wing of ¾″ width on each side of bar. This overfill being of a thickness equal to the parting in rolls. This showed a result which could at times be made use of in operation of mills.

Such facts are sometimes discovered only when cobbles are made, and roll shop men are usually on the look-out for such opportunities.

We have been benefited by Mr. Moses' paper this evening, and I am very glad to have been here to hear him.

C. R. HAND: Lubrication of rolling mills, as Mr. Moses has known for a good many years, have only recently received attention. Some of our mills at Sparrows Point, have all modern devices for lubrication. But some of the most modern and some of the older ones we are still using the original method of packing it on the necks and hoping it will stay.

As far as our newest mills are concerned, we have the Messinger and Mesta Bearings, forced feed lubrication, and we hope, adequate seals to keep out the water, that some of the earlier mills did not have and whose experiences with oil some times were far from satisfactory. I believe that is all I have, Mr. Chairman.

HARRY K. MAXWELL: I want to thank you first for the invitation to be present at this lecture. It is the first one I have attended of this kind, and I think the roll turning fraternity, if you want to call it that, would benefit very greatly if we had more of them. The subject, as Mr. Moses has stated it, has been covered very thoroughly in a general way, and as he stated at the outset of his lecture, he didn't want to go into much detail, but there is one question that comes under the flow of metal between rolls which I think those assembled here tonight would like some further explanation on, and that is as a bar or bloom enters the rolls in an open box pass or plain body rolls, is the spread uniform throughout the length of bar, or if the entering end spreads most, why is it?

LOUIS MOSES: If the bar is the same temperature throughout its length the spread will be the same at all points except perhaps at the extreme entering end. Sometimes there are conditions present which tend to spread the extreme end to a greater amount which cause difficulties in entering it between the succeeding guides, where otherwise there is ample room for the body of the bar. Temperature differences would be the chief cause of varying spread, I would say. The condition tending to increased spread at front ends is not precisely known. It might be that when the extreme end passes under the centerline of the roll faces it undergoes a reduction more in the nature of a momentary hammer blow than otherwise, which results in more spread than elongation. When the portions of the bar immediately back of the extreme front end reach the same location the roll pressures, as well as the inertia to shock, are steadier and from then on the normal spread would occur.

HARRY K. MAXWELL: That is the only question I have to ask Mr. Moses, and in conclusion permit me to thank you gentlemen for the opportunity of being here tonight, and listen to the presentation of this very interesting paper.

C. R. FOX: Mr. Chairman, I believe all of us benefited by hearing Mr. Moses' splendid paper; particularly on the temperature of steel, which at all times is a very important factor in the art of rolling regardless of section to be produced. We have found that in the rolling of strip, it is very essential that the temperature be uniform throughout, which is a great factor in eliminating camber, rolling true to gauge, and for producing material to meet the metallurgical requirements. I would, however, suggest to the gentlemen from Worcester regarding his difficulty with low carbon steel; that from previous experience with this grade of steel, I have found it could be rolled successfully by watching the temperature of soaking pits when charging and drawing; as well as locating the proper temperature, previous to entering the finishing stands.

J. R. ADAMS: Mr. Chairman, I came here distinctly as a guest, and if the gentleman before me thinks he is unprepared, I don't know what he thinks I am.

I want to congratulate Mr. Moses on a very lucid presentation of a most complicated subject, and think he presented it most clearly. I was much impressed in his exposition of the manner in which the steel flowed, spreads, etc. and I cannot help but wonder somewhat upon the effects of such differences—in rates of flow, on the physical properties of the steels, particularly alloy steels when they are rolled into sections. If anyone has any remarks on that phase of the situation, I think it would be of interest.

LOUIS MOSES: I have had no experience rolling shapes from alloy steel, Mr, Adams. Lacking definite information and required to do such a job I would proceed, so far as roll design is concerned, much the same way as with carbon grades. I would think that comparative densities would be of major importance. Differences in this respect, as found to exist in the finished product, would not necessarily be of similar magnitude when the material is at rolling temperature and the alloy might display flow tendencies similar to plain carbon steel. The heating would necessarily meet the material's temperature characteristics, clues to this being furnished by the metallurgist. By this I mean that the finished shape may, or may not, be subjected to a subsequent refining process, in either case rolling temperature with its effect on grain size, being of importance as affecting flow and deformation. Rolling speeds would affect scaling properties. I believe stainless steel offers difficulties, as compared with ordinary rolling methods, but I do not know what the differences are. High tensile plates do not display great differences in their rolling to carbon grades but close watchfulness is required in heating. In all of this we again must sing the refrain of the mill studying the material as well as the roll shop, and the two departments adapting practice accordingly.

W. E. GRAINGER: As a rank outsider to the rolling mill business, I would like to ask Mr. Moses or Mr. Fox, how the synchronization of roll speeds is accomplished in individual drive continuous mills?

LOUIS MOSES: So far as speed regulation of the stands of a continuous mill is concerned the original type of mill could be called a rigidly geared mill. A single line shaft has sets of gears, of varying ratios, mounted thereon which drive the respective stands at fixed variance to each other and which cannot be changed. There are a number of such mills at Sparrows Point. The continuous strip mill with which Mr. Fox has to deal has the individual stands each driven from its own separate variable speed motor. Prior to rolling any given gauge the speeds are predetermined by calculation and the operators told at what speed to run the motors. If the calculations are correctly made the bar goes through the mill as desired. Other conditions may cause a pull between one or a number of stands, or perhaps a loop will develop, in an extreme case it might even cobble. The behavior indicates to the operators what the trouble is and they act to vary either the speed or the roll setting accordingly. Does that describe the way you do it, Mr. Fox?

C. R. FOX: Mr. Chairman, Mr. Moses and I study out of the same book.

LOUIS MOSES: I dread the thought of the consequences if we lost our little black books.

F. O. SCHNURE: Answering the question regarding speed control of the finishing motors on hot strip mills, these motors usually have a standard speed regulation of 4% at no load, 2% at full load, and 4% at double load. This inherent regulation has been found satisfactory although several mills have been designed and built for a speed regulation of 1½% over the entire range. Such regulation represents an additional cost and the mills on which it has been used are in the minority.

L. F. COFFIN: Before discussing Mr. Moses' paper or asking him any questions, I wish to congratulate the Philadelphia Section upon branching out into this new field of steel mill engineering by presenting this paper tonight. From the response and interest shown, it is very evident that more papers on the subject of rolls, roll design and flow of metals should feature the activities of our Association. The Association of Iron and Steel Engineers can only be of service to the industry as it widens its activities, and this is evidently one of the directions in which this can be accomplished.

I would like to ask Mr. Moses to give us a little information as to the relation between angularity of bite and slippage and limiting factors in the reduction of sections in the flat rolling of steel.

LOUIS MOSES: To answer Mr. Coffin's question the mill operator is limited in the amount of draft he wants to take, for instance in a Blooming Mill, by the power of his motor, as Mr. Schnure says, as well as the grind and slip occasioned if the rolls do not bite. Again, as mentioned in the text of the paper you have just heard, we are limited by the nature and kind of material undergoing rolling. It is physically possible to apply a great deal more work than we do, in so far as the mill itself is concerned as a tool, but steel may be torn in doing so. I mentioned the wise metallurgist who hits the nail on the head by observing that the amount of work is limited by that which pulls the particles apart to an extent where they will not unite. I am getting into deep water when attempting to describe the physical makeup of Bessemer steel but I am perhaps safe in stating that its relatively higher sulphur and phosphorus content is arranged in some manner or another to become more or less of a lubricant between the grains. At any rate, whatever the reasons ascribed, Bessemer's analysis promotes more slippage, when hot, than is the case with Open Hearth steel. We find that in order to obtain a given reduction, in plain rolls, which is easily taken with Open Hearth grades, Bessemer will exhibit a characteristic slipping at the roll surfaces. Therefore the rolls are ragged, or roughened, to pull it through. For the same reasons, no doubt, the constitution of Bessemer allows the ragged markings to roll out and become erased on the finished bar. But if we put Open Hearth steel through such ragged rolls the chances are that the marks will show on the finished bar, particularly if the ragging has not been carefully done and well rounded. I believe that Mr. Phipps, Mr. Maxwell and Mr. Brown will bear me out on this. It is therefore very difficult to establish a rule for maximum drafting without naming a number of qualifying factors. The plotted curve of a series of area reductions generally appears as a parabola. The two extremes would be the heaviest possible draft at the start of the series of reductions and taper off to the lightest practical one for finishing to a close tolerance of gauge. A slight reduction of 2% or 3% would amount to barely more than planishing and the bar would act erratically because of the lack of pressures to hold it steady. Work here, under such conditions, would be increased.

Now back at the roughing end we want to take a big bite. Going back with reference to Figure 4 where the angle of a to c is generally taken as being not greater than 30 degrees. Taken otherwise in terms of the sine of the angle the total draft taken without ragging is somewhere near 10% of the diameter of the roll. Greater angularity of bites are generally accompanied, if no ragging is employed, by some extraneous means to push the bar into the rolls. A No. 1 stand of a continuous mill will take a comparatively heavy reduction unaided on plain rolls. The power of its delivered push will enable the next succeeding stand to accept a greater angularity of bite. Our Phoenix friend is interested in shapes. These are not as easily determined but they can be projected and an average obtained. With all the qualifications which I interject, Mr. Coffin, I sometimes am led to believe that our work is about one half guess work and two thirds luck. That adds to more than 100% but I need not mention that such is our rated efficiency, believe it or not.

GEORGE B. MCMEANS: I was interested in Mr. Moses' discussion of slip, especially in its relation to surface conditions on bars for rolling wire rods. I wonder if he would say a little more about the ragging that he talked about, especially where you have to get heavy reductions, and its possible effect on surface conditions. We must remember that occasionally you will run into a certain amount of decarburization due

to heating conditions and your ragging will tend to cause a tearing action in addition to the trouble caused by slip. I wonder if you can say a little more about ragging and whether you would recommend using inverse ragging or a knurling or pebbling effect on the rolls?

LOUIS MOSES: The trend of the times is to eliminate ragging wherever it is possible to do so. If it is not wisely applied and done with care it will offset much of the care expended at the steel works in pouring practice to obtain good skin on the ingots. Good results are obtained with the inverse type of ragging which consists of spaced bosses, or broad projections, on the faces of rolls. This bites into the bar as well as does the conventional grooving and has the advantage of there being no rolled projections on the bar to lap over or roll in. There are only a few instances of ragging on the mills where I work, as I said the effort is to confine it to places where it cannot be gotten rid of entirely. Where it is employed a careful check is made to see that the rolled product is not marred. If you can devise ways and means to get rid of it entirely, Mr. McMeans, you will have a better product.

C. R. FOX: Perhaps it would be of interest to the rolling mill operators here, that on our 79″ Hot Strip Mill at Lackawanna, it was necessary due to excessive draft for cross rolling purposes, to use an electric pusher on the No. 1 stand to stop slippage.

On the Sparrows Point installation, which is a straight away mill, it was not necessary to install a pusher. However, for other reasons, we fluted the bottom roll in No. 1 stand, which eliminates slippage and to-date have found no serious results from its use.

GEORGE B. MCMEANS: Thank you very much. Mr. Moses, I might say that we use a three-high mill which presents slip due to differences in roll diameters, and he covers the slip which governs our necessity for using ragging.

A MEMBER: Mr. Moses, can you tell me if the inter-molecular friction caused by the rolling would make the temperature of the piece being rolled higher after rolling than immediately before?

LOUIS MOSES: I cannot answer that from experience. I would say that any work applied to a bar creates additional heat but in ordinary rolling its effects would be slight. The old time blacksmith would sometimes show off his ability to bring a cold rod of iron to a red heat by placing it on his anvil and rapidly raining blows with his hand hammer upon it.

W. T. MILLER: That roll work produces heating of the metal being rolled, can be seen, when rolling a small bar, by looping on a standard straight train mill. When a mill hand misses the bar while looping same from one set of rolls to the next set, the bar which is in contact with the mill floor, becomes cooler and nearly black, because of this delay. As soon as the bar is retrieved and passes through the rolls it immediately glows red.

Regarding the ragging of rolls, causing defects on the surface of steels, I understand that some mills overcome this effect by grinding slightly concave bands part way across the plain or bullhead portion of their blooming mill rolls at regularly spaced intervals around the circumferences. A cross section of the roll so ragged will have the appearance of a many sided regular polygon. This type of ragging while enhancing the bite will not cause serious injury to the steel being rolled.

On our mills rolling alloy steels, we do not resort to any type of ragging. Occasionally on newly dressed roughing rolls, it is difficult to enter some grades of billets into the starting passes. Sometimes our rollers pour acid on these passes to roughen their surfaces, as this practice is somewhat dangerous, it is being discontinued as a safety precaution.

On some mills due to the diameter and the speed it becomes difficult to enter a 4″ square into a reducing oval, it may be better to use a flat diamond to accomplish this reduction to the next square.

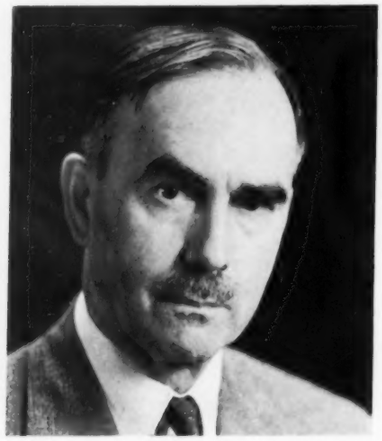
GEORGE B. MCMEANS: I would like to ask one more question. Mr. Moses, can you point out any advantages or differences in rolling when you have big end up ingots, in entering the big ends into the rolls or rolling the small end first. Is there any laboratory metallurgical advantage?

LOUIS MOSES: I could easily get along with a better grasp of the subject than I now have. There are blooming mill men here who can better answer it. I would say that rolling small end first, if the ingot is is top cast, small end up, will promote ease in the shears cutting discard to sound steel. By such a means the length of sound steel is determined and the yield, as measured by the number of multiple cuts, increased without danger of the last cut being piped. Small end entry is easier to manipulate as compared with butt first rolling.

GEORGE B. MCMEANS: I realize there will be a lot of guide trouble rolling the small end first, but I wondered whether any of you present thought there would be any advantage in rolling the small end first.

W. PAUL GERHART: To answer that man's question, there is one advantage in rolling a big end up ingot, or any ingot for that matter, with the bottom end first to the mill, in that the increase in fishtail is at the top of the ingot where the discard is taken where in rolling the opposite way the fishtail is increased at the bottom where you have your sounder steel. As far as the internal condition of the steel, I don't think it makes any difference.

PROTECTIVE A
for ANNEALING F
STEEL M



A. N. OTIS

▲ THE subject of atmospheres for furnaces has engaged the attention of numerous investigators, and the literature contains many valuable references.

The earlier work refers more especially to atmospheres for carburizing, while the later work refers extensively to the protective properties of gases for bright annealing, as well as for preventing decarburization.

Most of these papers treat the subject from the scientific viewpoint, recording the results of experiments in the laboratory, and there is some lack of agreement in the results reported, due in part to failure to recognize the effects of impurities such as oxygen and water vapor. Nevertheless, they form the basis upon which much of the recent progress in this field has been founded, and the later work, particularly, is of real application value.

The importance of suitable protective atmospheres for annealing furnaces in steel mills can hardly be over emphasized, and while the use of such atmospheres is being rapidly extended, yet there is much information which has not been put into such form as to be readily available to those who actually use the apparatus.

It is not the writer's purpose to review the work of the investigators, but rather by drawing from them, and from experience, to define the requirements for atmospheres for such purposes as bright annealing sheets and strip, annealing carbon and alloy steel bar stock, silicon steel sheets, stainless steel, etc. Also to describe apparatus for some of these applications, and to point out the limitations and extent of purification required for atmospheres for these processes.

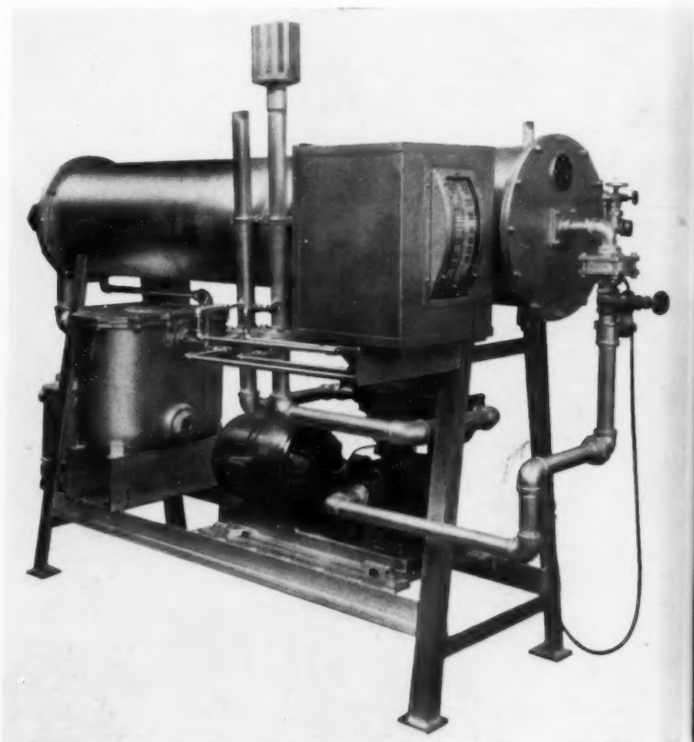
Since success depends upon the selection of the proper atmospheres for the specific purpose, and its subsequent treatments to remove objectionable elements, it is essential that the operators have a clear understanding of the functions of the apparatus, the effects of the impurities, and the extent to which they should be removed.

Also, for annealing some of the more sensitive materials ,to be referred to later, it is necessary that the furnaces be of proper design for the process, otherwise the value of purified gases may be nullified. The importance of this fact is not always appreciated, and sometimes appears to be overlooked.

The literature gives adequate basic information and scientific facts regarding atmospheres, but it is necessary for the reader to give close study, to numerous references, and to make calculations and interpretations, in order to secure the required data and apply it to these problems. It is therefore considered that an approach from the practical standpoint of the user or operator would be helpful, if confined specifically to a limited group of subjects.

There are so many applications of protective atmospheres, such as for hardening dies, high speed tools, machined parts, etc., that they could not possibly be covered within the scope of the present paper. Many of these are high-temperature, short-time treatments,

Figure 1—Combustion-type furnace atmosphere controller, 2000 cu. ft. per hour output capacity.



ATMOSPHERES FURNACES *in* MILLS

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Presented before the A. I. & S. E. Annual Convention, Chicago, Illinois, September 28, 29, 30, October 1, 1937

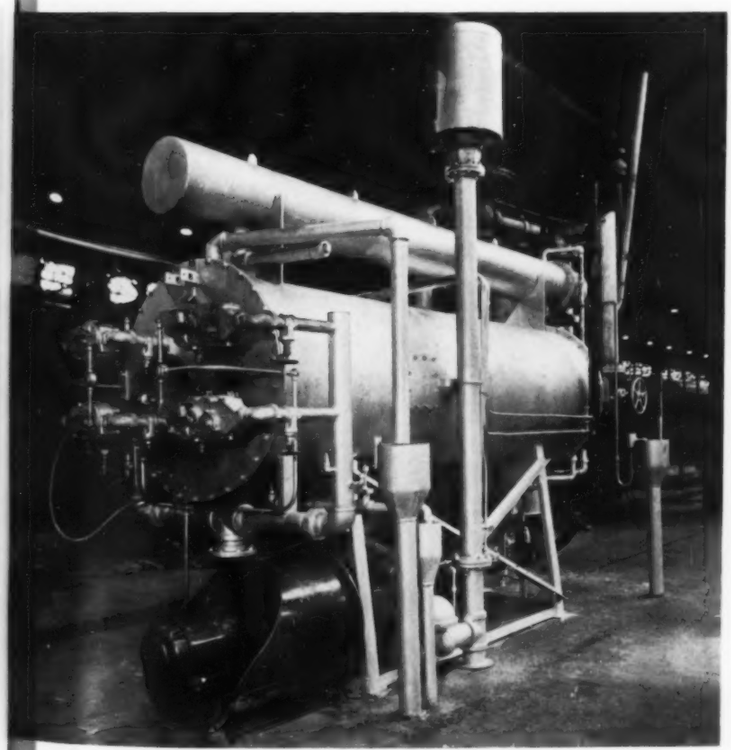
while steel mill operations are usually long-time treatments, with slow cooling.

For these reasons it is intended to confine the present remarks to typical applications in steel mills.

LOW CARBON STEEL

The largest single application in the mills today is for annealing bright sheets and strip. This is of great economic importance and fortunately it is one of the simplest of the processes that require protective atmospheres. Most of the mills now have apparatus for producing atmosphere for this purpose, consisting of equipment for partially burning coke-oven gas or natural gas under controlled conditions.

Figure 2—Combustion-type furnace atmosphere controller, 15,000 cu. ft. per hour output capacity.



This apparatus, although introduced only a few years ago, has come into wide use through the advantages which it offers, namely, a cleaner and better product, at lower cost, and with greater safety, than is possible by the use of raw gas, as formerly employed.

Typical equipments for reforming these fuel gases are shown in Figures 1 and 2, the former being of 2000 cu. ft. per hour output capacity, and the latter 15,000 cu. ft. per hour capacity. They consist of a combustion chamber, with suitable burners, metering devices, and motor-driven compressor for air-gas mixture, also a surface cooler, to cool the product gas to approximately the temperature of the available tap water. This removes the moisture content to the dew-point corresponding to that temperature.

The combustion chamber contains a firing bed of suitable refractory material, which has been treated with a catalyst. This aids in producing the required reactions, the result being partial dissociation and partial combustion of the fuel gas.

Typical analyses of the product gas from these machines is given in Table I. The moisture content will vary from 2½% (cooling to 75° F.) to 1% (cooling to 45° F.), depending on the temperature of the available cooling water. Columns 1 and 2 are for coke-oven gas and natural gas respectively, burned at the usually operated ratios for annealing bright steel.

TABLE I

TYPICAL ANALYSES OF BURNED FUEL GASES

	Coke Oven Gas Ratio Air to Gas 2½ to 1	Natural Gas Ratio Air to Gas 6 to 1	Either Gas Full Combustion
	(1)	(2)	(3)
CO_2	4.0	4.5	11.5
O_2	0.0	0.0	.0 to trace
CO	9.5	10.5	.5
CH_4	1.4	1.0	.0 " "
H_2	20.8	16.0	.4
N_2	64.3	68.0	87.6

It will be noted that coke-oven gas gives a somewhat higher hydrogen content than natural gas.

Column 3 is for a gas for annealing copper, and for some other applications requiring inert atmosphere, and it may be further modified by removing the CO_2. If then dried, it is suitable for annealing material having mill scale on the surface, and for other purposes, as will be outlined later.

The results secured by the use of this apparatus have been very gratifying, and users as well as prospective users generally, are familiar with its features and operation. However, the effects of the hydrogen content, and particularly the permissible or desirable moisture content, are, apparently, not fully understood.

In some cases, absorption dryers are considered, for the purpose of removing the moisture content to a very low value, and, as is well known, refrigerated coolers are often employed, to remove it to a moderate value, while other operators get entirely satisfactory results, under their conditions, without the use of either.

The laws governing the reactions in these complex gas mixtures were outlined by Marshall[1] in 1933, with experimental data to confirm. It was shown that some gases, if too dry, will etch bright steel, producing a grey matte finish, particularly if the CO content is high. It was also shown that for some of the gases tested, a considerable moisture content is permissible; that it could be varied over a wide range; and, in some mixtures, was made as high as 20% without change in appearance of bright steel.

Since this portion of Marshall's work is particularly pertinent, it will be reviewed, and the essential facts restated, together with relations existing between hydrogen and water-vapor, i. e., the extent to which water-vapor may be present without oxidation while cooling, thus avoiding the cost of unnecessary removal. Also, an attempt will be made to amplify some of Marshall's results.

Before proceeding, it is desirable to fix in mind the relative moisture content of gases.

For this purpose, Figure 3 has been prepared. It shows the moisture content, and corresponding condensing temperature or "dew-point" of gas, saturated at a higher temperature, and then cooled to a lower temperature.

When a gas so saturated is further cooled, a part of its moisture is eliminated as water, and may be drained off. This applies downward, nearly to the freezing point. The water then becomes ice.

For extracting moisture below the freezing point, absorption dryers are available. These employ materials that absorb and hold moisture, but it may be driven off upon subsequent heating, the material being thus reactivated, and again ready for use.

Such dryers are usually made with two chambers, one for use while the other is being reactivated. They can be designed, when required, to remove moisture almost completely. They are exceedingly valuable for applications which require really dry gases.

The lower portion of the curve has been replotted at a 10 to 1 scale, for convenience in reading the extreme lower or "dry" portion, which will be required for later reference.

[1]Trans. American Society for Metals, Vol. 22—page 605, 1934, A. L. Marshall, "Bright Annealing of Steel in Mixed Gas Atmospheres".

The normal range of usefulness of water coolers, refrigerated coolers, and absorption dryers is also indicated.

It will be noted that as temperature increases, the curve becomes steeper, indicating the rapidly increasing effect of temperature on the holding power of the gas for moisture.

There are two problems involved in annealing bright steel, (a) etching, which occurs at annealing temperature and (b), oxidation or blueing, which occurs at low temperature, during cooling, due to free oxygen, or to a too high moisture content as related to the hydrogen content.

Etching

Etching, evidenced by a gray matte finish on the surface of bright steel, occurs during the high temperature portion of the annealing cycle, due to the producer-gas and water-gas reactions. (1) and (2), as explained by Marshall.

$$2CO = CO_2 + C \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$CO_2 + H_2 = CO + H_2O \quad \ldots\ldots\ldots\ldots (2)$$

Etching will result if the gas mixture is too high in CO, and too low in water-vapor, i. e., if the proportions are too far from equilibrium, as related to the amount of CO_2 and hydrogen in the mixture.

Plainly stated, a small amount of water-vapor is required in these complex mixtures, to secure equilibrium of the component gases with each other, when at high temperatures. If water-vapor is not present in sufficient quantity for equilibrium, the component gases will tend to dissociate and recombine to establish equilibrium, the necessary water-vapor for equilibrium being formed as a product. The steel acts as a catalyst

Figure 3—Moisture content of gas at various temperatures, when saturated and cooled to a lower temperature.

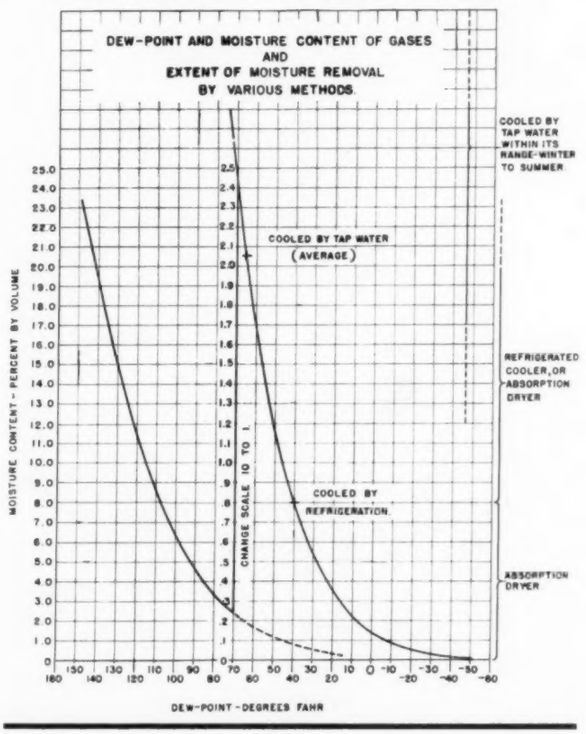

DEW-POINT AND MOISTURE CONTENT OF GASES
AND
EXTENT OF MOISTURE REMOVAL
BY VARIOUS METHODS
COOLED BY TAP WATER WITHIN ITS RANGE-WINTER TO SUMMER
COOLED BY TAP WATER (AVERAGE)
REFRIGERATED COOLER, OR ABSORPTION DRYER
COOLED BY REFRIGERATION
ABSORPTION DRYER
MOISTURE CONTENT - PERCENT BY VOLUME
CHANGE SCALE 10 TO 1
DEW-POINT - DEGREES FAHR

TABLE II

EFFECT OF ADDING WATER-VAPOR AND CO_2 TO HYDROGEN-CO MIXTURE, FOR ANNEALING BRIGHT STEEL. A. L. MARSHALL

	CO	CO_2	H_2	Water Vapor	Dew Point	Surface Condition of Annealed Bright Steel
Case I = Percent	22.	1.0	75.	0.6	32° F.	Etched—Dull grey matte
Case II = Percent	18.	7.0	60.	13.5	126° F.	Bright—Unchanged

for the reaction, and its surface becomes roughened in the process.

Marshall's work is a pioneering one on this subject, and it covers a wide range of gas analyses. We refer to only one portion of it however, namely, the phenomenon of etching and blueing, and their elimination by proper hydrogen and water-vapor contents, with one type of gas.

After stating the equilibrium laws, and some conclusions from his work, Marshall says that; (for temperatures up to 650 C = 1200 F).

"Experiment has shown that if the ratio $(CO)^2$ to (CO_2) be less than about 0.4, the ratio $(CO) \times (H_2O)$ to $(CO_2) \times (H_2)$ may be as low as .06 to .07 before etching begins to appear."

This is basic data, and to show its effect, he annealed samples in a gas mixture consisting almost wholly of hydrogen and CO. The characteristic etched surface resulted, as would be expected, since the gas was relatively dry.

He then increased the CO_2 and water-vapor substantially, and found that the surface of the steel was unchanged during the anneal.

The gas analyses and water-vapor content is given in Table II. It will be noted that the water-vapor content is very high (13.5%) for the latter test.

Now let us calculate the ratios, and apply Marshall's rule:

CASE I

$$\frac{(CO)^2}{(CO_2)} = \frac{.22 \times .22}{.01} = \frac{.0484}{.01} = 4.84$$

$$\frac{(CO) \times (H_2O)}{(CO_2) \times (H_2)} = \frac{.22 \times .006}{.01 \times .75} = \frac{.00132}{.0075} = .176$$

MARSHALL'S RULE

If $\frac{(CO)^2}{CO_2}$ is less than about 0.4.

$\frac{(CO) \times (H_2O)}{(CO_2) \times (H_2)}$ may be as low as .06 to .07.

CASE II

$$\frac{(CO)^2}{(CO_2)} = \frac{.18 \times .18}{.07} = \frac{.0324}{.07} = .463$$

$$\frac{(CO) \times (H_2O)}{(CO_2) \times (H_2)} = \frac{.18 \times .135}{.07 \times .60} = \frac{.0243}{.042} = .58$$

Assume Case II gas to be refrigerated to 45° F., and thus contain 1% moisture, other quantities remaining the same, for illustration.

$$\frac{(CO) \times (H_2O)}{(CO_2) \times (H_2)} = \frac{.18 \times .01}{.07 \times .60} = \frac{.0018}{.042} = .043$$

This would be likely to etch the steel, since it is well below the value .06 to .07 given.

With 2% water vapor, dew-point 64° F., it should be satisfactory, thus

$$\frac{(CO) \times (H_2O)}{(CO_2) \times (H_2)} = \frac{.18 \times .02}{.07 \times .60} = \frac{.0036}{.042} = .086$$

Marshall calls the ratio $\frac{(CO)^2}{(CO_2)}$ the "producer-gas content", and the ratio $\frac{(CO) \times (H_2O)}{(CO_2) \times (H_2)}$ the "water-gas content."

The calculations following the table are made in order to show the values of the ratios $\frac{(CO)^2}{(CO_2)}$ and $\frac{(CO) \times (H_2O)}{(CO_2) \times (H_2)}$ for the conditions existing. It will be noted that for Case I, the ratio $\frac{(CO)^2}{(CO_2)}$ is more than 10 times the value for Case II, and that while the ratio $\frac{(CO) \times (H_2O)}{(CO_2) \times (H_2)} = .176$ is well above the value .06 to .07 quoted, the preponderance of $\frac{(CO)^2}{(CO_2)}$ ratio would be expected to cause etching.

Case II gives a $\frac{(CO)^2}{(CO_2)}$ ratio of .463, which is close to the value 0.4 quoted, and the ratio $\frac{(CO) \times (H_2O)}{(CO_2) \times (H_2)} = .58$ is well above the lower limit of .06 to .07 quoted.

It should therefore be satisfactory, which the test shows.

The lower limit would be approached by reducing the water-vapor content to 2% (dew-point 64° F.), thus indicating the wide range of moisture content permissible with the particular gas used—from 2% to 13.5%.

It should be noted that the gas used is high in hydrogen (60%), and was made from tanked supplies. It is also high in CO, and represents an extreme case, for emphasis.

Similar tests were made with partially burned gas, from machines as shown in Figures 1 and 2, with exactly similar results, The analyses and moisture contents are given in Table III.

It should be noted that Marshalls' work was done at temperatures up to 650 deg. C. (1200 deg. F.). It is known that reaction rates are faster at higher temperatures, but the conditions necessary to prevent etching at higher temperatures have not been studied.

However, temperatures of 1300 to 1350 degrees are regularly employed in some mills, using the partially burned gas described for atmosphere, and entirely satisfactory results are secured. Therefore, for the annealing range of low-carbon steel, the subject in which we are now interested, we know that the gas is satisfactory.

CASE I—TABLE III)

$$\frac{(CO)^2}{(CO_2)} = \frac{.1 \times .1}{.048} = \frac{.01}{.048} = .208$$ (Well below 0.4 quoted).

$$\frac{(CO) \times (H_2O)}{(CO_2) \times (H_2)} = \frac{.1 \times .0018}{.048 \times .196} = \frac{.00018}{.0094} = .0192$$

This is too far below the minimum of .06 to .07 quoted, and would be expected to etch.

CASE II

$$\frac{(CO) \times (H_2O)}{(CO_2) \times (H_2)} = \frac{.1 \times .026}{.048 \times .196} = \frac{.0026}{.0094} = .276$$

This is well above the minimum of .06 to .07 quoted, and should anneal bright.

It is thus apparent that the laws governing these reactions are known, and that simple calculations, as outlined, are sufficient to determine whether a given gas is likely to etch bright steel. Also it will be evident that very dry gases are detrimental to bright annealing steel, and that excessive drying should be avoided for this reason, as well as for the cost of unnecessary moisture removal.

The moisture content is readily adjustable and thus easy to control. It may sometimes make usable, gases that otherwise would be unfit.

It will be of interest, and perhaps of value, to show the effect on the ratio $\frac{(CO) \times (H_2O)}{(CO_2) \times (H_2)}$ by varying the moisture content over a wide range.

For this, let us assume the normal mixture of partially burned fuel gas, as regularly used for bright annealing steel. It would have approximate analysis of;

$CO = 10\%$
$CO_2 = 5\%$
$H_2 = 20\%$
$N_2 =$ Balance.

This would be obtained by burning coke-over gas, TableI, at 2½ to 1 ratio. If cooled in a surface cooler, with normal water temperature, it would have amoisture content of about 2%, corresponding to dew-point of 64 deg. F. The effect of varying the moisture content is shown in Table IV, and a column for gas with 10% Hydrogen has been added, to be used for later reference.

Extensive experience has shown that with a gas having sufficient hydrogen content, cooling into the range of 60° F., gives ample protection against blueing making further drying unnecessary. Also that it will not etch the steel. The latter is substantiated by theory, and by the calculations given. Excessive dryness is unnecessary and, in fact, is undesirable.

The permissible moisture content to anneal without blueing will now be discussed.

Oxidation or Blueing—Relation to Hydrogen Content

Blueing occurs during cooling, and is caused either by free oxygen, or by too high a moisture content relative to the hydrogen present. A high hydrogen content is desirable, since it permits more moisture to be present without harmful results, and saves the cost of moisture removal, beyond the extent necessa'y to secure a bright product.

Figure 4 shows the relation between water-vapor and hydrogen, for equilibrium with iron at various temperatures, also for CO and CO_2.

We are now interested in the lower part of the cooling range, because, at higher temperatures, a considerable water-vapor content is permissible. For example at 1000 deg. F., the ratio $\frac{H_2O}{H_2}$ may be 0.25, as shown by the curve. At lower temperatures the ratio must be

Figure 4—Equilibrium relations for oxidation and reduction, of gases containing CO and CO_2, and hydrogen and water-vapor.

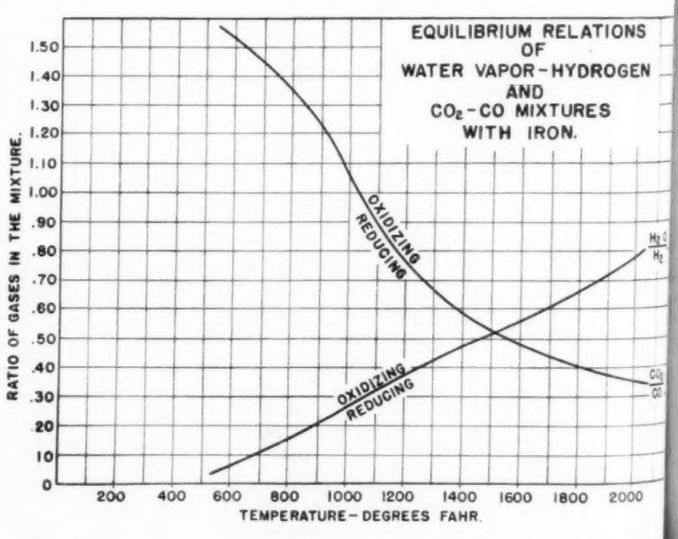


TABLE III

EFFECT OF ADDING WATER VAPOR TO PARTIALLY BURNED FUEL GAS

	CO	CO_2	H_2	Water Vapor	Dew Point	Surface Condition of Bright Steel
Case I = Percent	10.	4.8	19.6	.18	5° F.	Etched, dull grey matte
Case II = Percent		Same		2.6	72° F.	Bright, Unchanged

TABLE IV

EFFECT OF THE RATIO BY VARYING MOISTURE CONTENT OVER A WIDE RANGE

NORMAL MIXTURE, 2.5 TO 1 RATIO—20% H_2

% H_2O	Dew Point Deg. F.	$\frac{(CO) \times (H_2O)}{(CO_2) \times (H2\ )}$	Same Gas With 10% H_2	Normal Operating Range for.
.1	Minus 9	$\frac{.1 \times .001}{.05 \times .20} = \frac{.0001}{.01} = .01$	.02	Absorption Dryer
.5	28	$\frac{.1 \times .005}{.01} = \frac{.0005}{.01} = .05$	.10	Too dry—likely to etch.
1.0	46	$\frac{.1 \times .01}{01} = \frac{001}{.01} = .1$	.2	Refrigerator
2.0	64	$\frac{.1 \times .02}{.01} = \frac{.002}{.01} = .2$	.4	Surface Cooler
3.0	75	$\frac{.1 \times .03}{.01} = \frac{.003}{01} = .3$	.6	
4.0	84	$\frac{.1 \times .04}{.01} = \frac{004}{.01} = .4$	.8	
6.0	98	$\frac{.01 \times .06}{.01} = \frac{.006}{.01} = .6$	—	Excessive moisture likely to oxidize or blue the steel.
10.0	115	$\frac{.1 \times .1}{.01} = \frac{.01}{.01} = 1.0$	—	

It will be noted that the ratio is well above the minimum value of .06 to .07 given, for all except the very dry conditions obtainable with absorption dryers. These are likely to etch.

less, because the power of hydrogen to prevent oxidation by water-vapor, decreases with temperature.

At 700 deg. F. it is 0.1.

Taking the normal mixture just referred to containing 20% hydrogen and 2% water-vapor, (dew-point 64 deg. F.), the ratio $\frac{H_2O}{H_2} = .1$, and is shown to be in equilibrium at 700° F. Above this temperature it is strongly reducing, lying to the right of the equilibrium line.

As the load cools through 700 deg. F., the effect of the atmosphere would theoretically change from reducing to oxidizing. But the reactions are slow near equilibrium, and are further slowed by lower temperature. Furthermore, it will be noted that the ratio $\frac{CO_2}{CO} = \frac{5}{10} = .5$ is strongly on the reducing side of the upper curve. Thus the CO aids in maintaining the atmosphere in a reducing or neutral state, preventing the formation of iron oxide.

If the atmosphere contained only 10% hydrogen the ratio $\frac{H_2O}{H_2} = \frac{2}{10} = .2$, and this would be at equilibrium as the load cools through 900 deg. F. The reactions are faster at higher temperatures, and this would probably be near the danger point, since it would be oxidizing as the load cools further.

With a gas low in hydrogen, therefore, it is necessary to lower the water-vapor content to correspond, keeping the ratio $\frac{H_2O}{H_2}$ equal to about 0.1. Thus, with 10% hydrogen for a ratio of .1, the water-vapor content would have to be 1%, corresponding to dew-point 45 deg. F., and this gas must therefore be cooled 20 degrees lower than would be required if it contained 20% hydrogen. Likewise, a gas with 5% hydrogen, could not contain more than 5% water-vapor, (dew-point 28 deg. F.), to give ratio of .1.

The data exhibited by Figure 4 is of considerable interest. It will be noted that the slopes of the curves are in opposite directions.

This means that the CO_2 tends to be more oxidizing at higher temperatures than at low temperatures while the reverse is true of water-vapor. At 1500 deg. F., both ratios could be .5, that is, one half as much CO_2 as CO would be allowable, and one half as much water-vapor as hydrogen.

The CO_2 would not oxidize while cooling (moving to the left), but the water-vapor would, and most decidedly. For this reason the $\frac{H_2O}{H_2}$ ratio should be about .1, as outlined, which is strongly reducing at the higher temperatures, and is sufficiently so while cooling to prevent oxidation. It is aided also by the upper curve, which is diverging, and therefore, its reducing effect increases as the load cools—while the reducing effect of the lower curve decreases.

For the application in which we are now interested, it is convenient to remember that the gas should contain twice as much CO as CO_2, and 10 times as much hydrogen as water-vapor.

It is interesting to note, and also a fortunate coincidence, that the gas from machines Figures 1 and 2, under normal operating conditions, meets these requirements exactly.

Range Between Conditions for Etching and Blueing —Relation to Hydrogen Content

When the moisture content of a low-hydrogen gas is reduced, in order to avoid blueing, it will be obvious that conditions likely to produce etching will be approached.

Etching is not likely to occur with gases cooled by surface coolers or by refrigeration, because the dryness readily procurable by these methods is not sufficient to cause etching. Absorption dryers, however, might readily dry the gas into the etching range.

The range or spread between the conditions for etching and for blueing, or "operating range", is greatly increased by additional hydrogen content.

This is shown graphically by Figure 5. This graph uses the gas and data from Table IV, and shows the effect of reducing the hydrogen content to 10% and 5%. Round figures are used for simple calculation, and for convenience of illustration.

The ratio $\frac{H_2O}{H_2} = .1$ has been assumed in all cases as the limit for blueing, and .06 to .07 for etching.

The range for the three conditions are:

Hydrogen Per Cent	Water-Vapor Per Cent	Temperature Range Deg. Fahr.	Drying Means Required
20	.6 to 2.0	33 to 64	Surface cooler or refrigerator. (This gas is used successfully up to 77 deg. F.)
10	.35 to 1.0	18 to 45	Refrigeration required.
5	.15 to .5	Zero to 28	Absorption Dryer required.
Pure	0 to 9	up to 110	

It is interesting to note that the range of temperature degrees is about the same in all three cases, but the range of actual moisture content increases rapidly with the hydrogen.

Pure hydrogen does not etch, therefore its range is from no moisture to 9% moisture (for ratio of .1), which is equivalent to saturation at 110 deg. F.

Gas from machines illustrated by Figures 1 and 2, is successfully used, in several large installations, where in hot weather the gas leaves the coolers at 77 deg. F. Conversely installations are known where the gas must be cooled to 40 deg. F. or lower, in order to avoid blueing.

The foregoing explains, as briefly as is possible with necessary clearness, the effects of hydrogen and water-vapor in these complex mixtures, for bright annealing

EFFECT OF HYDROGEN CONTENT ON PERMISSIBLE RANGE OF MOISTURE CONTENT IN PARTIALLY BURNED GASES, (TABLE FOUR) FOR BRIGHT-ANNEALING STEEL

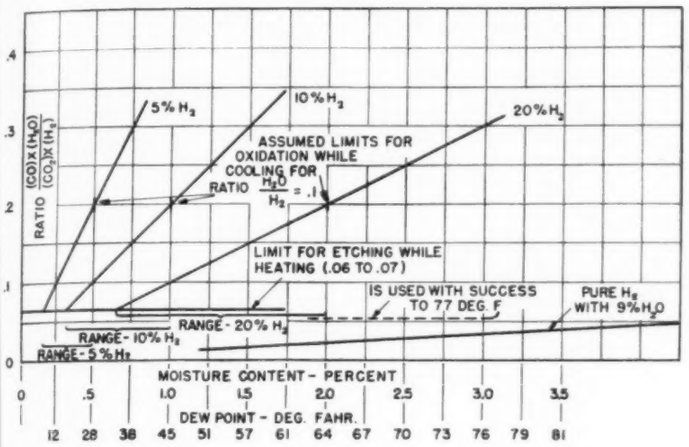

RATIO (CO)X(H2O) / (CO2)X(H2)
5% H2
10% H2
20% H2
ASSUMED LIMITS FOR OXIDATION WHILE COOLING FOR RATIO H2O/H2 = .1
LIMIT FOR ETCHING WHILE HEATING (.06 TO .07)
IS USED WITH SUCCESS TO 77 DEG. F
PURE H2 WITH 9% H2O
RANGE - 10% H2
RANGE - 20% H2
RANGE - 5% H2
MOISTURE CONTENT - PERCENT
DEW POINT - DEG. FAHR.

Figure 5—Range between conditions for etching and for blueing, for gases with various hydrogen contents, containing also CO and CO_2. Data from Table IV.

steel. It may help to account for some apparent inconsistencies met with in operation.

In order to prevent blueing, it is important that air or oxygen be kept out of the gas, and out of the annealing chambers. The foregoing assumes that no oxygen is present.

It may be found in practice, that satisfactory results are secured without strict adherence to the equilibriums given. The equilibriums assume indefinite time, at constant temperature, and are the theoretical conditions under which the chemical reactions take place. They therefore form the basis for guidance, but certain latitude in operation may be found to be practicable. For example, tests have shown a moisture content as high as 5.5% (dew-point 95 deg. F.) in the gas described, when discharging from annealing boxes. Yet, a bright anneal was secured.

Coolers and Dryers

The machines illustrated by Figures 1 and 2 employ tubular-type surface coolers for cooling the gas from the combustion chamber. The tubes are mounted in a water jacket, being surrounded by water, the gas flowing through the tubes. The gas is thus cooled nearly to the temperature of the cooling water, and dried to the corresponding dew-point. Cooling is accomplished in an entirely closed system, which precludes the possibility of air or oxygen contamination of the gas.

For annealing bright steel, the gas should preferably be cooled to 70 deg. F. or lower, which can be readily be done with ordinary water supply available. In hot summer months, or in localities where cool water is not available, it may be necessary to use supplementary cooling, for which standard refrigeration units are available.

It may not be necessary to use refrigeration except for a few months of the year, and then only to the extent necessary to cool the gas to 60 deg. F., or whatever temperature has been found to give satisfactory results with the particular gas used.

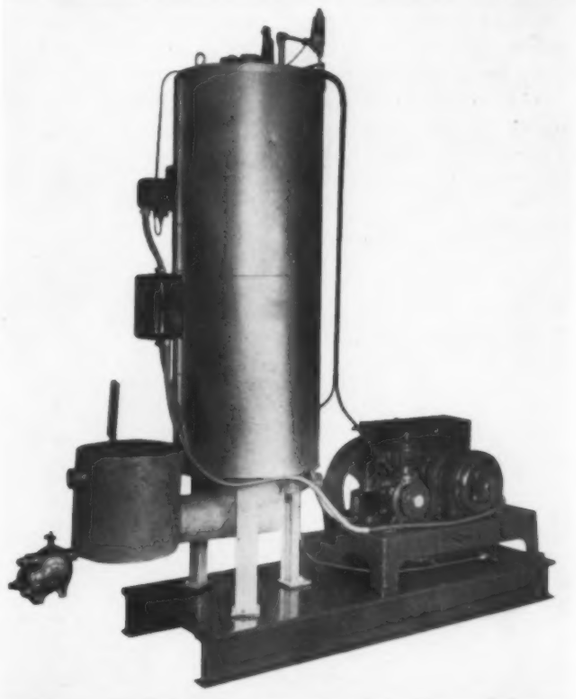
A recording thermometer will give a true indication of moisture content of a gas that has been saturated at a higher temperature and immediately cooled. It does not give a true indication of a dryer gas. The thermometer should be located at the discharge end of the cooler.

Pipes should be sloped and drained, to prevent accumulation of water, which might be condensed from moist gas, when the mill becomes cold. Also, high moisture contents, even though permissible, should be avoided on account of the likelihood of excessive condensation in the distributing lines.

Figure 6 shows a typical refrigerated gas cooler. It consists of a standard motor-driven condensing unit, as used with commercial refrigeration installations, and an insulated tank, containing cold water. There are two coils of copper tubing immersed in the water, one coil for the refrigerant and the other for the gas to be cooled. Suitable regulating and temperature control devices are also included.

Figure 7 shows a typical absorption dryer for gases. It consists of two chambers, one of which is normally in use while the other is being reactivated. It is provided with the necessary heating means for driving off absorbed moisture, and the necessary regulating and control devices. They can be designed for almost any gas capacity or moisture-removing capacity. They are

Figure 6—Refrigerated cooler for atmosphere gas, capacity 2000 cu. ft. per hour.



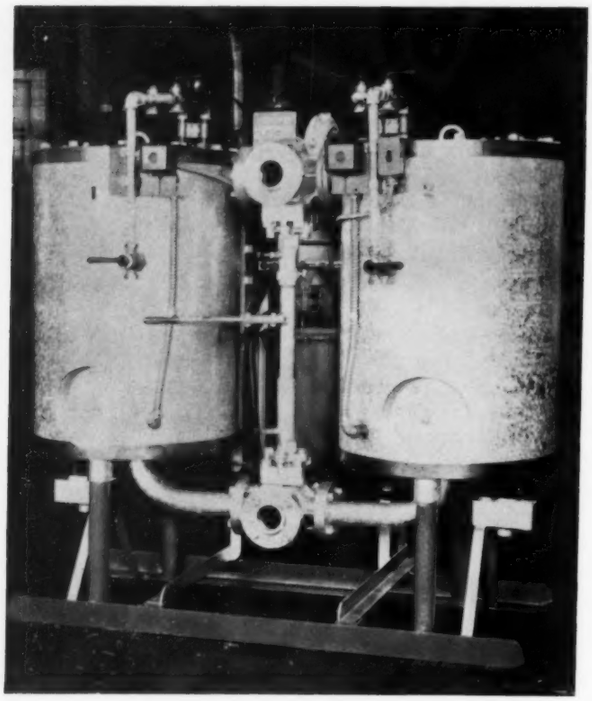


Figure 7—Absorption dryer, for drying gases. Exceedingly low moisture content is readily obtainable.

indispensible where larger volumes of very dry gases are required.

Special apparatus is required for measuring the moisture content of dry gases. The laboratory method is to pass a known volume of the gas over moisture-absorbing chemicals, the amount of moisture being determined by careful weighing.

A more practical apparatus consists of a small chamber through which a stream of the gas flows continuously, one side of the chamber containing a thin metallic mirror, with thermo-couple attached, and arranged to read the dew-point temperature directly. Such an instrument is referred to and described later. It is illustrated by Figure 16.

Typical Installation of Electric Furnaces for Low-Carbon Steel

Figure 8 shows a typical installation of electric bell-type furnaces, for annealing coils of wide and narrow strip, employing gas apparatus like Figure 1. No supplemental drying is employed, and bright steel is secured the year around. The gas apparatus is shown in the right background.

The furnaces take loads of 9 to 10 tons, heating cycle 18 hours, the furnace bases being equipped with motor-driven fans and the retorts with water spray rings, to accelerate the cooling.

There are five furnaces in the installation, each having three bases.

There are numerous installations of these and similar furnaces, where no refrigerators or dryers are employed for the atmosphere gas. Others do employ them when required.

HIGH CARBON STEEL

For annealing high carbon steel, two problems are presented, (1) for bright or clean materials, such as cold rolled strip, and (2) for hot rolled materials, such as bar stock or strip, having mill scale on the surface. Gases having reducing properties are desirable for the former, in order to prevent discoloration while cooling, but for materials with mill scale, neutral gases are required, since the reaction of reducing gases with the mill scale, at annealing temperatures, produces decarburizing elements.

(1) For Bright Materials

Coke-oven gas purified of oxygen and water vapor is suitable for protection against decarburization, but the methane content (it contains approximately 55% H_2 and 35% CH_4) tends to decompose, leaving a carbon deposit on the work, particularly at high annealing temperatures. At 1300 to 1350 deg. F., the usual annealing temperature for carbon steel strip, the carbon deposit is not excessive, and the product is satisfactory to some users. If work is to be done at higher temperatures however, a considerable carbon deposit must be expected.

Figure 9 shows the dissociation characteristic of methane (CH_4), or the equilibrium between hydrogen-carbon-methane. At 1300-1350 deg. F. the curve is quite steep, indicating rapid approach to breakdown or low methane content, with corresponding soot deposit.

Purified coke-oven gas has one decided advantage, namely, that it tends to carburize rather than decarburize, and therefore offers definite protection against loss of carbon from the steel. This is due to the presence of methane.

For high-grade materials, such as razor blade strip, where the high finish must be preserved in the anneal, dissociated ammonia is sometimes preferred. Although this gas is relatively expensive, it meets the requirements splendidly, and its use is often considered justified for these special purposes.

While dissociated ammonia, due to its high hydrogen content (H_2 75%, N_2 25%) will tend to decarburize slightly at high temperatures, at the usual annealing temperature of 1300 to 1350 deg. F. the rate is exceedingly slow, and for practical purposes is imperceptible, if care is taken to keep out oxygen and water vapor.

Unusual care is required for annealing this high grade material, both in the design of the furnaces and in the use of the gas. For example with electric bell-type furnaces, now used extensively for this purpose, the loading bases are provided with a gas-tight sheet alloy cover over the brickwork. This is to prevent traces of air, or moisture from the air, being absorbed by exposed brickwork while the bases are open to the room, and later being driven off in the annealing chamber when at high temperature.

Some operators also pass the dissociated ammonia through absorption dryers, to remove any moisture which might possibly be present as impurity. This precaution, and the use of covered bases as outlined, indicates the great care exercised by some producers in the manufacture of these materials.

Earlier writers have shown the decarburizing effects of hydrogen, but the extent of purification is not stated,

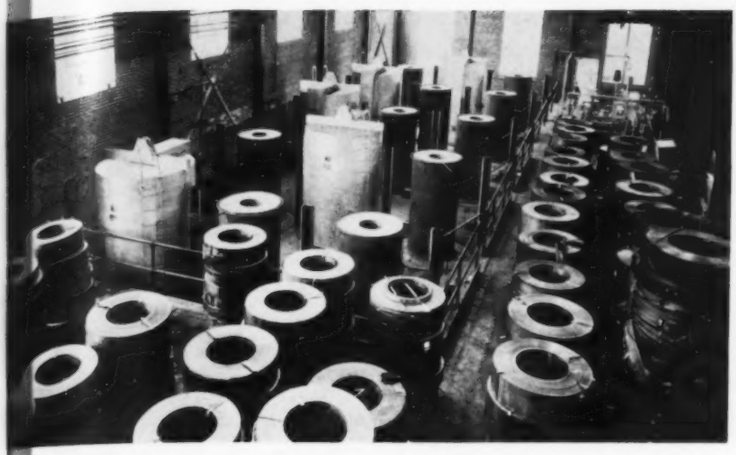


Figure 8—Typical installation of bell type electric furnaces for coils of low-carbon strip.

and there is therefore reason to suspect impurities. Several years ago Austin[2] made a very careful study of this subject. He worked with highly purified gas, both completely dry and with known additions of water-vapor. He used steel with 1.10% carbon and also alloy steel (SAE-52100), at temperatures of 800 deg. C. (1472 deg. F.), and 55 hours time.

Curves are given showing the extent of decarburization with pure dry hudrogen and with moisture additions as follows:

10 milligrams per cu.ft. = (dew-point minus 25 deg. F.).
50 milligrams per cu. ft. = dew-point 10 deg. F.
150 milligrams per cu. ft. = dew-point 35 deg. F.
Saturated—(temperature not stated)—probably about 60 deg. F.

He has shown that pure dry hydrogen decarburizes slightly, but is practically nil at the usual annealing temperatures. Quite surprisingly, he found that a slight amount of water-vapor is helpful. The best results were secured with 10 m.g. of water-vapor per cu. ft.

He states that:

"The dry gas tests show the reaction to be extremely slow at 775 deg. C. (1427 deg. F.). At 950 deg. C. (1742 deg. F.), a marked increase in the rate of decarburization was observed, and the penetration effect was much deeper".

And again:

"The structures (micro) for pure dry hydrogen and for 10 m.g. of water-vapor per cu. ft., indicate practically no surface decarburization".

The structures referred to are for 1.10 carbon steel, held 55 hours 800 deg. C. (1472 deg. F.) in dry hydrogen, and 55 hours at 750 deg. C. (1382 deg. F.) in hydrogen with 10 m.g. of water-vapor per cu. ft. added.

He further states that:

"Early experiments (his), also demonstrated that ordinary dry hydrogen decarburized so slowly at 775 deg. C. or 950 deg. C. (1427 or 1742 deg. F.), even after

[2]Trans. American Society for Metals, Vol. 22—page 31, 1934, C. R. Austin, "A Study of the Effect of Water-Vapor on the Surface Decarburization of Steel by Hydrogen, With Certain Developments in Gas Purification".

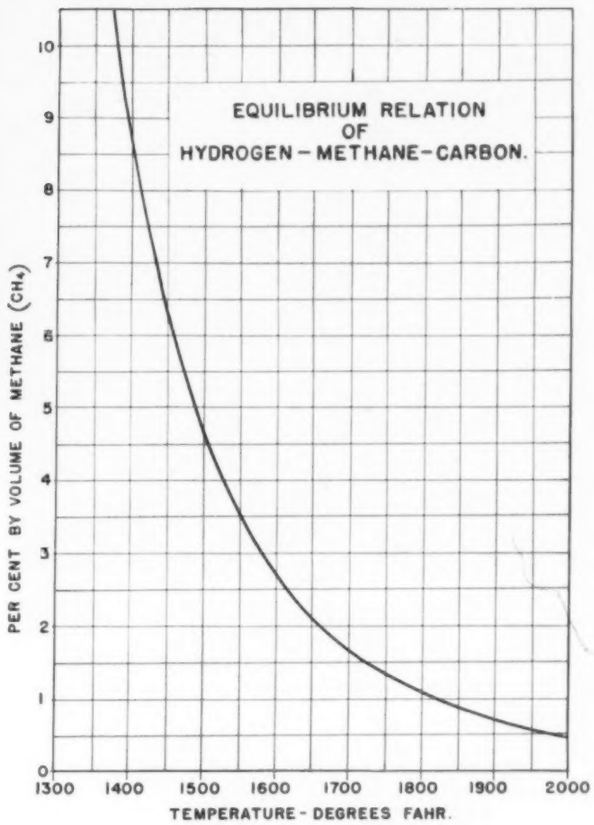


Figure 9—Equilibrium relation of hydrogen-methane-carbon in gas at various temperatures.

Figure 10—Bell-type electric furnace, with covered bases, for annealing high-carbon steel strip in atmosphere of dissociated ammonia.

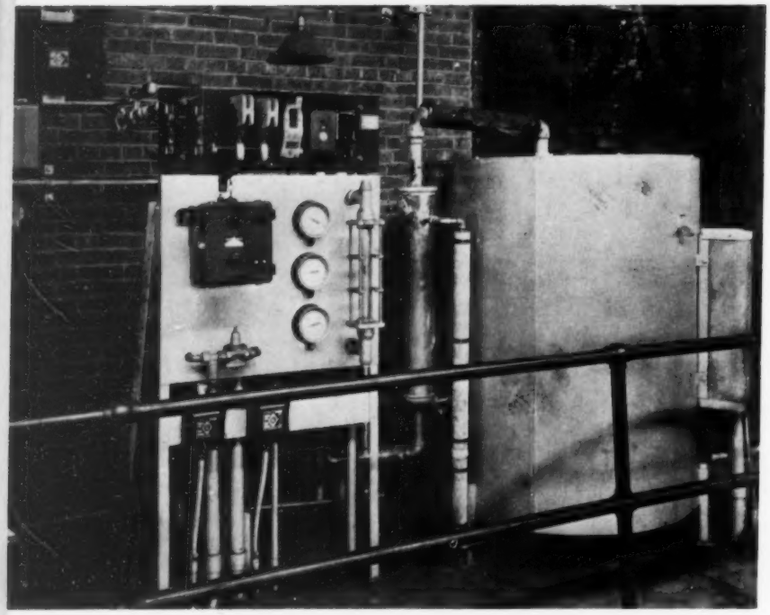


Figure 11—Equipment for dissociating ammonia, capacity 1000 cu. ft. per hour.

several hours at test, that chemical analysis was necessary to determine definitely that a reduction in peripheral carbon content had been effected".

His tests with dry dissociated ammonia (on SAE-52100 steel) showed no perceptible decarburization up to 26 hours at 775 deg. C. (1427 deg. F.), but in 50 hours it was perceptible.

The foregoing shows why dissociated ammonia is suitable for annealing bright high-carbon materials, and confirms the results of practice. It should be repeated however, that unusual care is required in handling these materials, and the furnace equipment must be suited to the process, if the best results are to be secured.

Figure 10 shows part of a typical installation of bell-type furnaces for annealing coiled strip of high-carbon steel. Dissociated ammonia is used for atmosphere, and the bases are covered with sheet alloy. Figure 11 shows an equipment for dissociating liquid ammonia. It consists of a vertical cylindrical electric furnace, containing the dissociator unit proper, and a panel for mounting the necessary pressure gauges, flow meter, temperature control instrument, etc.

The equipment shown has capacity to produce 1000 cu. ft. per hour of dissociated gas.

Since, at high temperatures, coke oven gas will form a soot deposit, and dissociated ammonia will tend slightly to decarburize, due to the impracticability of removing all traces of oxygen from the furnace chamber, also due to the relatively high cost of ammonia, neither of these gases completely fulfills the requirements for general use.

Developments have been made, of partially burned gases, suitably mixed and treated, with the object of providing an atmosphere, at relatively low cost, that would be suitable for the purpose.

Both coke oven gas and dissociated ammonia are explosive, and certain hazards must necessarily attend their use.

An ideal atmosphere for annealing these bright high-carbon materials would be one that is low in cost, readily available, of low hazard, and it should not oxidize, etch, decarburize or form a soot deposit through the entire annealing range of the materials.

As the equilibrium relations indicate, no readily-available "natural" mixture has all of these desirable properties.

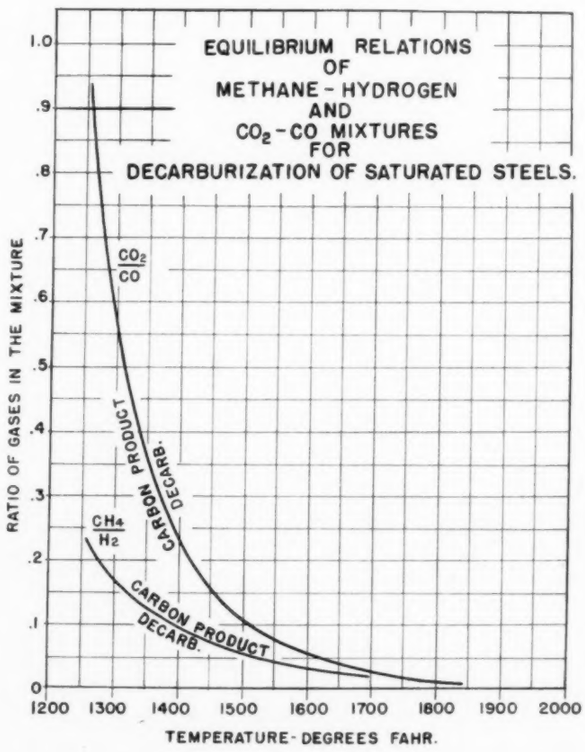
Dry nitrogen meets all of these requirements in the laboratory but, with large size equipments, it is difficult to purge the annealing chamber of the last traces of oxygen and water-vapor. Discoloration while cooling is therefore likely to occur.

With additions of CO, or methane, to nitrogen, its properties are improved, but to protect from oxidation while cooling, an appreciable hydrogen content is desirable.

Hydrogen, in the presence of CO, and if the gas is dry, will tend to produce the undesirable reactions outlined by Marshall. The desirable mixture therefore is nitrogen, hydrogen and methane, which would be equivalent to coke-oven gas diluted with nitrogen.

Nitrogen may be produced by burning the gas in Table I to full combustion and removing the CO_2. It may then be mixed in the proper proportions with coke-oven gas (largely hydrogen and methane). The

Figure 12—Equilibrium relation of gases containing CO and CO_2, also gases containing hydrogen and methane, to saturated steel.



mixture, of course, should be dried. Only a small methane content is required to prevent decarburization by hydrogen, as numerous investigators have shown. See also Figure 12.

Obviously, such a mixture combines the desirable properties of both coke-oven gas and dissociated ammonia, ie, the hydrogen is low, eliminating the hazard, the cost of the gas is low, and the low methane content assures protection from decarburization, without soot deposit. Such a gas, therefore, has the necessary properties for annealing most or all of these bright high-carbon materials.

While the foregoing illustrates, by simple method, the principles involved in the requirements and preparation of such a protective gas, other methods are available by means of which hydro-carbon gases can be treated to secure the desired result.

These developments will prove of great importance to the industry in the future, as a means of improving the quality of high-carbon products.

(2) Material With Mill Scale on the Surface

Atmospheres containing hydrogen will react with the mill scale (iron oxide) to form water vapor, and if CO is present it will react with the scale to form CO_2. Since both water vapor and CO_2 are decarburizing, they must be avoided.

The atmosphere must therefore be inert, for which the only readily available gas is nitrogen. This can be produced by burning a fuel gas, column 3 of Table I, and purifying it of water-vapor and CO_2 as outlined.

Apparatus is available for removing both of these elements, the resulting atmosphere consisting almost wholly of nitrogen preferably with small amounts of hydrogen and CO, which will tend to loosen the mill scale and facilitate cleaning. This is desirable if the bars are to be cold finished.

Most hot rolled products have a slight surface decarburization, which takes place while heating, rolling, or cooling in air after rolling. The usual requirement is to preserve the existing condition of the material while annealing, that is, to prevent further decarburization. The mill scale itself tends to protect against further decarburization, and of course the problem of protecting the surface against discoloration or etching is not present, as in the case of bright materials. Therefore, an atmosphere for this purpose presents no technical obstacles, although the design of the furnace and the correct method of operation are important, if the best results are to be secured.

The curves of Figure 12 show the equilibrium relations of gases containing CO and CO_2, also for gases containing hydrogen and methane, to steel saturated with carbon. It will be noted that the CO_2 content must be reduced as annealing temperature is increased, in order to avoid decarburization. The other curve shows that only a slight methane content is required to prevent decarburization by hydrogen.

These curves are for clean steel, i.e. without mill scale, but the upper curve will show the necessity of a low CO_2 content, when annealing these materials, either with or without mill scale. An inert gas, free of water-vapor is clearly indicated for this application. Apparatus for removing CO_2 from gases, is illustrated by Figure 13. Gas, from column 3 of Table I, when so treated, and dried, would thus be suitable.

Removal is accomplished by the use of a liquid absorber, which dissolves the CO_2 and holds it in solution. Upon subsequent heating, the CO_2 is driven off. The liquid is cooled and is again ready for use, thus making the process continuous and regenerative.

The equipment consists of two towers, one for absorbing the CO_2 and the other for driving it off, the liquid being continuously circulated between the towers by means of a pump. The CO_2 may be removed completely, or with only traces remaining.

Other types of CO_2 removers are also in use for small applications. These employ chemicals to absorb and hold the CO_2 gas in combination. The chemicals have to be renewed frequently, if low-value of CO_2 is required.

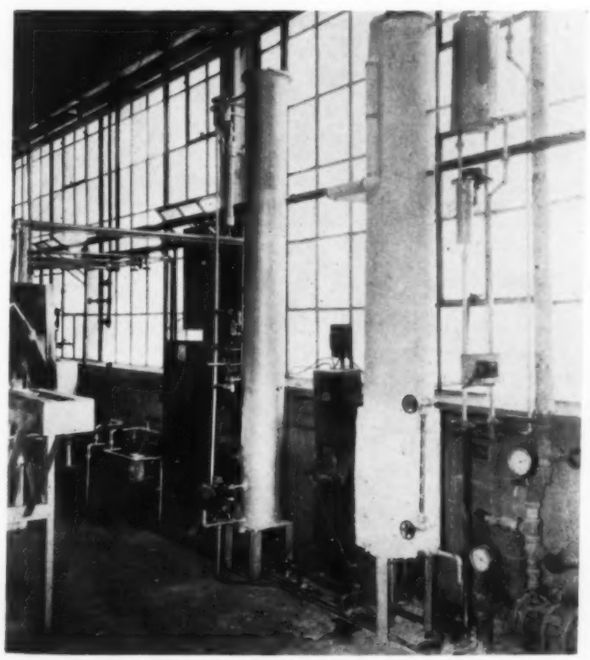
The continuous, regenerative equipment described, gives constant results, with a minimum of attention, and where larger volumes of gas are required, it is to be preferred.

Apparatus for removing water-vapor by cooling, refrigeration and absorption drying have been previously described. They are necessary for the application now being discussed.

A furnace for annealing these materials should be gas-tight, to prevent infiltration of air, and the opening should be provided with oil seals. The brickwork should be kept warm at all times, so that it cannot absorb air or moisture.

A rectangular bell-type furnace, with liquid seal channel around the edge of the base or car, fulfills these

Figure 13—Equipment for removing CO_2 from atmosphere gas. Capacity 500 cu. ft. per hour.



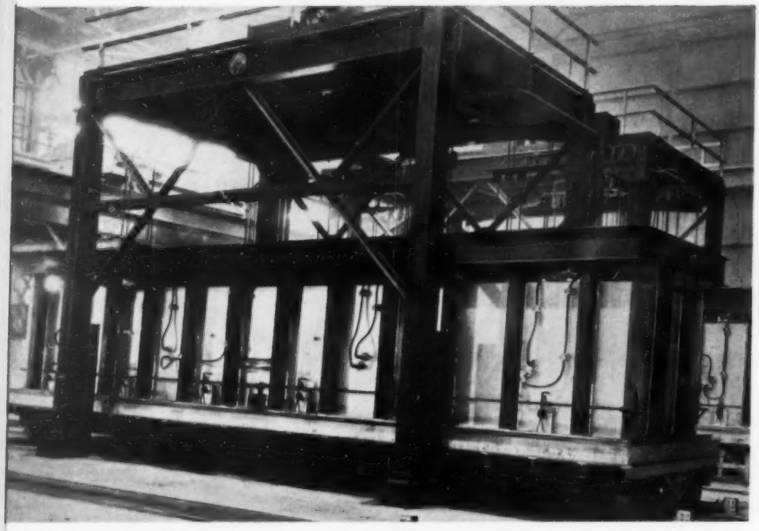


Figure 14—Pair of rectangular bell-type electric furnaces for bar stock, with heating chambers sealed to the cars by liquid seals.

requirements. A pair of such furnaces, for heat-treating bar stock, is shown in Figure 14. They have car-type bases, and fixed motor-driven hoists for raising the heating chambers.

OTHER APPLICATIONS

It is sometimes desired, in annealing materials, with mill scale, that carbon be added to the surface, if possible, in order to make up, in part, for the loss of carbon while rolling. This latter requirement, however, while technically possible, presents certain difficulties in controlling the carburizing component, and, so far as the writer knows, a suitable atmosphere for it has not yet been put into practical use, in large size furnaces.

An atmosphere obtained by partial combustion and then removing the water-vapor and CO_2 products, is used successfully for heat-treating formed or machined parts without decarburization.

The time in the furnace for such operations is relatively short as compared to most annealing operations, and etching, or discoloration of the surface is of less importance than with bright materials. Also, since such parts are usually quenched, they are not subject, as are annealed materials, to long exposure in the cooling range.

Silicon Steel

Silicon steel, or so-called electrical sheets, are made in several grades, but reference to high grade only is made herein. The requirements for annealing this material are exacting, in that it is necessary to secure the lowest magnetic losses obtainable with a given type of steel; the sheets must be clean and free from oxidation; they must be flat; and should be so annealed that brittleness is avoided.

An annealing temperature of approximately 1900 degrees F. is necessary or desirable, and this high annealing temperature, together with uncontrolled conditions as to heating and cooling cycles, atmosphere, and temperature, may result in the sheets having one or more of the undesirable qualities mentioned.

Theory and experience indicate the necessity of a pure dry atmosphere, from which all oxygen, sulphur, or water-vapor have been removed. This latter requirement also necessitates that the brickwork of the furnace be thoroughly dry, and be maintained so, and that the bases should not be allowed to become cold, so that they will absorb air or moisture.

When a pile of sheets is heated to annealing temperature, a large volume of gas is given off the sheets and the carbon content of the sheets is thereby gradually reduced.

Experience also indicates that it is necessary to rid the sheets, also the surrounding atmosphere, of these detrimental gases, this being one object of the anneal, that is, to purify the sheets. This assists materially in obtaining lower magnetic losses.

The detrimental effect of moisture in the atmosphere increases with temperature, as it tends to oxidize the the silicon, and thus to increase the magnetic losses. Therefore, for these high-temperature operations equipment is necessary to dry the atmosphere to a very low dew-point, making it practically moisture-free.

Much experimental work has been done to determine the effect of various atmosphere gases on the magnetic losses, experiments having been conducted in pure dry hydrogen, pure dry nitrogen, and in pure mixtures of hydrogen and nitrogen. These experiments leave no room for doubt that the magnetic qualities are improved substantially by annealing in pure dry hydrogen, as compared with pure dry nitrogen, and they also leave no doubt as to the less beneficial effects of nitrogen if present with hydrogen, in any proportions.

These experiments, however, were conducted on laboratory samples, in which the size of the annealed strips are such that the atmosphere gases can penetrate between them and thus effectively reach the surfaces.

With a large stack of wide sheets, it is questionable whether the atmosphere gas can attain access to the surfaces between the sheets of the stack, and there is, therefore, a question as to whether improved magnetic qualities would be secured with pure hydrogen, as compared with pure nitrogen, in the cases of these large loads. It appears safe to assume that the effect on the magnetic qualities would probably not be of such magnitude as would justify, at least for the present, the greater expense and difficulty of annealing in hydrogen.

It is certain, however, that the gases driven off by the steel should be swept out immediately, particularly when the steel is at high temperature, so that they will not have an opportunity to react with the steel, thus considering the annealing process as a purifying one. Also as stated previously ,the atmosphere, should be free of oxygen, water vapor, sulphur, and carbon products. Nitrogen, when purified and dried, thus provides a good annealing gas and probably as good as any obtainable.

This atmosphere can be produced in the combustion type equipment, supplemented by suitable purifiers and dryers, and is the same as described for annealing hot rolled materials.

Part of an installation of rectangular bell-type furnaces for annealing silicon steel sheets, is shown in Fig. 15. These furnaces are arranged to be lifted by

the mill crane, and the bases are stationary. They are provided with oil seals between the heating chamber and the bases. The casings are gas-tight.

Stainless Steel

Bright stainless steel is exceedingly sensitive to discoloration by even slight traces of oxygen or water vapor. Strip of this material has been annealed in a small continuous furnace in the laboratory, with splendid results.

For this work, highly purified hydrogen was used, it being introduced into an inner tube or muffle, located inside the usual muffle tube, ordinary hydrogen being introduced into the outer muffle and completely surrounding the inner muffle, ends and all. The strip is cooled before emerging from the inner muffle.

If only the single muffle be used, good results cannot be obtained regardless of the purity of the hydrogen, because according to molecular laws, small amounts of air or water vapor will diffuse into the furnace openings or adhere to the strip itself. In the apparatus used, these are consumed in the outer muffle, before the strip enters the inner muffle and sufficient outward flow of purified gas is maintained through the openings of the inner muffle to prevent inward diffusion.

This apparatus, described by Kelly[2], while of small size, demonstrates perfectly the principles involved, and the high purity of atmosphere required. The practical importance of such a furnace remains to be demonstrated, but the point to be emphasized at this time is the requirements of the process.

Since the strip moves continuously, the time in the furnace is short, also, the chamber is of small volume. These conditions undoubtedly are helpful, since it is difficult to secure or to maintain high purity in the atmosphere of a large chamber. For example, it appears doubtful if a large batch of this material could be heated and cooled, requiring considerable time in a relatively large chamber, and remain bright, regardless of the care exercised in building the furnace or purifying the atmosphere.

Austin, in connection with the purification of his gases for decarburization tests, states that: "An even greater sensitivity to free oxygen and/or water-vapor is exhibited by stainless steel. The gas which was purified by the method outlined (by him), and which would chemically be regarded as pure hydrogen plus nitrogen, rapidly oxidized a stainless steel strip which was subject to an anneal in the gas. . . . . .Stainless strip was used in the subsequent series of experiments, to indicate when a really "pure" gas had been obtained."

These references indicate the extreme sensitivity of stainless steel, and the futility of attempting to bright anneal it with any apparatus not of refined type.

While the case of stainless steel is extreme, it emphasizes also the care required with other sensitive materials of which high-carbon steel is one, and the necessity of good and suitably designed apparatus for the purpose.

3Technical Publication No. 388 Am. Institute of Mining and Met. Engineers, F. C. Kelly—"Bright Annealing of Steels in Hydrogen", Abstract in Transactions—Vol. 95 (Iron and Steel)—Page 378.

Figure 15—Part of an installation of rectangular bell-type electric furnaces for annealing sheets of silicon steel. Heating chamber sealed to bases with liquid seals.

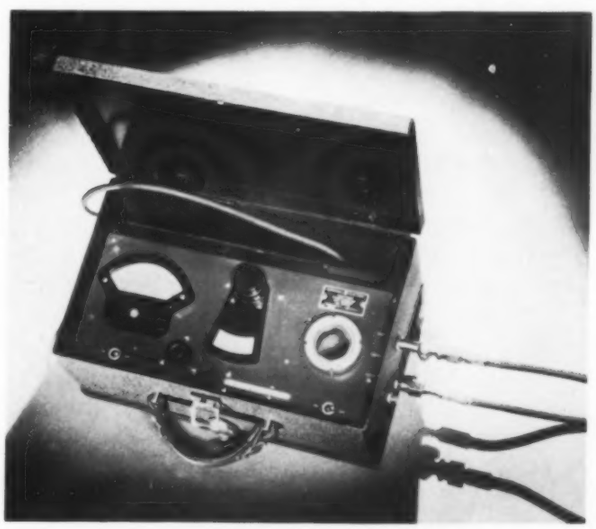
Instrument for Measuring the Moisture Content of Gases

The importance of the water-vapor content of gases used in annealing operations, has been sufficiently emphasized and, as has been pointed out, reliable apparatus is available by means of which the water-vapor content can be controlled and reduced any extent desired.

However, there has not been available a convenient and reliable means which the operators could employ, to quickly and accurately determine the water-vapor content, and thus enable them to effectively control it.

The instrument illustrated by Figure 16 has been developed to meet this need. It is a portable testing equipment, employing the dew-point principle. It is called a "Dew-point Potentiometer".

Figure 16—Dew-point Potentiometer, for measuring the moisture content of gases.



A stream of the gas to be tested is flowed through a compartment of the instrument in contact with a thin metal mirror, the mirror being provided with a thermocouple, so that its temperature may be read.

A window is provided on the opposite side permitting the mirror to be seen, and provision must be made for cooling the mirror. This may be done by a jet of air, passed through a pipe packed in dry ice, or other suitable means, such as compressed gas from a storage cylinder. The extent to which the mirror must be cooled, for a given test, will determine the cooling means required.

When moisture forms and disappears on the mirror, by slight adjustments of the cooling means, it indicates the dew-point with high accuracy.

The temperature of the mirror is read on an indicating meter, with its scale calibrated directly in temperature degrees. The range is 130 to minus 40 degrees Fahrenheit.

This is an exceedingly sensitive instrument and it is convenient to use. It is accurate for all practical purposes, that is, for all except minute traces of moisture, present in gases that are nearly "bone dry"—such as might sometimes be required in scientific investigations.

CONCLUSION AND SUMMARY

It is apparent to those who have studied these applications, that basic data, experience, and reliable apparatus are available to justify a still wider use of protective atmospheres for the annealing operations in steel mills. Such equipment would undoubtedly aid in the production of material of higher quality and greater degree of uniformity, with more certainty of securing the desired results, as well as offering the possibility of reducing the cost of the annealing or subsequent operations.

The number and nature of inquiries received for this apparatus, indicates a keen and growing interest on the part of operating men, and it may confidently be expected that protective atmospheres will play an increasingly important part in the annealing operations of the future.

SUMMARY

1—Bright steel will be etched during annealing in gases containing CO, CO_2 and hydrogen, unless a sufficient amount of water-vapor is present. This has been shown by Marshall[1].

It will be blued while cooling if the water-vapor content is too high with relation to the hydrogen present.

2—With types of protective gases now regularly used (if they contain sufficient hydrogen), the water-vapor content may be varied over a wide range, without etching or blueing. Simple calculations, with examples given, will determine the approximate lower and upper limits of moisture content. (Lower for etching, upper for blueing.)

3—For bright high-carbon steel, the moisture should be removed completely, since it is decarburizing. Dissociated ammonia is suitable as a protective gas for this material. It is used quite extensively at present, particularly for the finish anneal of high-grade products. The decarburizing effects of hydrogen are outlined.
Apparatus is available for re-forming and treating hydrocarbon gases for this purpose. The principles are outlined.

4—Material with mill scale on the surface requires an inert gas, preferably slightly reducing, which may be secured by combustion of fuel gas, the products of combustion being purified of CO_2 and water-vapor.

5—Equipment for producing and purifying protective gases is illustrated and described.

6—Some of these annealing operations are exceedingly delicate, and carefully designed furnace equipment is necessary. Typical examples of such furnaces are given.

For these applications both air and moisture must be kept out of the annealing chamber, and only suitable gases, that have been purified, should be put in.

7—An accurate and convenient instrument has been developed for measuring the moisture content of gases.

DISCUSSION

PRESENTED BY

J. H. STRASSBURGER, Steam Engineer, Weirton Steel Company, Weirton, West Virginia.

H. C. BARNES, Engineering Department, American Rolling Mill Company, Middletown, Ohio.

C. E. PECK, Manager, Industrial Department, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pennsylvania.

R. J. McCUIGAN, Metallurgical Engineer, Wheeling Steel Corporation, Steubenville, Ohio.

A. N. OTIS, Industrial Department, General Electric Company, Schenectady, N. Y.

J. H. STRASSBURGER: The subject "Protective Atmospheres for Annealing Furnaces in Steel Mills" as just given by Mr. Otis is a very complete treatise on this subject and the information given by the author should be of great value to the engineers and operators in the steel industry for obtaining satisfactory and improved results in the use of protective atmospheres.

In the Weirton Plants of the Weirton Steel Company protective atmospheres are being used in all the light

gauge finishing departments for producing a bright finish on sheets, strips and tin plate. In the past, straight coke oven gas had been used after being purified in dry box purifiers so that the sulphur content was reduced from approximately 550 grains of H_2S per 100 cu. ft. to approximately one grain per 100 cu. ft.

In conjunction with the use of this gas, cracking towers were installed to crack the gas before it was used in the annealing pots. The cracking process aided in reducing carbon deposition on the steel and also cracked the carbon bi-sulphide into carbon and H_2S; the hydrogen sulphide being removed by secondary purifiers. The use of straight coke oven gas has now been entirely displaced with atmosphere gas units which partially burn the gas, with refrigerators for reducing the water vapor content. Satisfactory results have been obtained with gas from this equipment and a typical analysis is as follows:

CO_2— 4.1%
CO —10.0%
CH_4— .3%
Hydrogen—16.8%
Gas temperature leaving machine—35° F.
Dew point at exit of machine —40° F.
Dew point in distribution lines —41° F.

The moisture content corresponding to 40° F. dew point is approximately .8% by volume so that the above analysis indicates a 20 to 1 relation between hydrogen and water vapor.

Cooling towers have been used for recirculating the water required by the gas cooling towers and for the refrigerating machines. Recently deaerator tanks were installed in order to reduce the air content of the water, because investigation had showed that at intervals there was some discoloration on the steel obtained due to air in the water supply. The water from the cooling tank is now discharged into a baffled tank open to the atmosphere so that the air can bubble out of the water. The pump suction is on the opposite of the tank from the water inlet so that the deaerated water, free from agitation, can be piped to the pumps.

H. C. BARNES: Protective atmospheres for annealing furnaces is a subject of great importance, and is now receiving the general study it deserves. Rapid progress is being made both in the equipment for generating protective atmospheres and in the methods of application to the furnaces.

Mr. Otis has given us a very interesting and complete paper, and is to be complimented on his contribution to the information available on this subject.

Most of the protective atmospheres used in steel mills are for the bright annealing of low carbon sheets and strip, which are annealed at moderate temperatures, 1350° F. and less, and my discussion will be limited to this phase of the subject.

The products of the partial combustion of natural gas or coke oven gas with refrigeration to remove excess water vapor to a moderate value, has been found very satisfactory for this application. This gas is considerably cheaper than raw natural or coke oven gas, since about 6 cu. ft. of bright anneal gas are produced per cu. ft. of natural gas, and a better product is obtained due to the elimination of soot and carbon stains on the sheets. Until recently, refrigeration was the most economical method of moderately reducing the water vapor concentration but the absorption systems have now been improved until they are becoming competitive with refrigeration.

As pointed out by Mr. Otis, there is considerable difference of opinion as to the permissible water vapor concentration, and when trouble develops in the bright annealing practice there is a tendency to blame it on too much moisture in the gas. Laboratory tests indicate that a concentration of about 5 grains water vapor per cu. ft. or 55° F. dew point, is necessary to produce any oxide border on low carbon steel at 1350° F. The usual dew point of 40° F. or a little less, obtained with refrigeration, allows a suitable margin of safety below this if there are no other interfering influences.

A dew point of 40° corresponds to 2.86 grains of moisture per cu. ft. or 0.83% by volume. The usual bright annealing gas produced from the partial combustion of natural gas contains about 5.5% CO_2, 10% CO and 9% H_2. At these concentrations, the equilibrium constant of the water gas reaction

$$CO_2+H_2 = CO+H_2O$$

has such a value that there will be an interchange of oxygen, reducing some CO_2 to CO and oxidizing some H_2 to H_2O. The equilibrium water vapor concentration for these conditions at 1300° is 1.25% corresponding to 51° F. dew point which is dangerously close to the limiting value of 55° F. If the fuel gas ratio is not closely controlled in the gas atmosphere machine there may be surges of CO_2 above 5.5% which will cause water vapor concentrations above 55° dew point in the hot gases in contact with the strip, even though the gas was dried to below 40° dew point before entering the furnace. Although this cause of high water vapor can be reduced by further drying of the cold gas before use, it is more economical to control it by closely controlling the gas-air ratio and prevent any high CO_2 concentrations even for short periods. At the concentrations leaving the gas generating machine, the CO_2 is more oxidizing than the water vapor, and it would be more logical to remove part of the CO_2 by absorption than to remove the water vapor to extremely low concentrations.

Another source of water vapor pickup is the gases given off by the steel during the heating cycle. In one series of tests natural gas with no CO_2 and 10° dew point was used as the protective gas in box annealing. Water vapor concentrations up to 55° dew point were obtained during part of the heating cycle. These boxes were unusually well sealed and there was less bleeding and flushing out of evolved gases than occurs in regular box annealing practice. The gases evolved during heating may also contain as high as 30% CO_2 which will cause serious oxide border unless they are flushed out before the steel is up to temperature. In some cases the leakage through the sand seal provides sufficient flushing out but in some cases it is necessary to provide a bleeder pipe to sweep out the evolved gases fast enough to prevent damage.

An interesting case of moisture pick up occurred during the winter at one plant. It was observed that bright annealing was poor during the warm spells following each cold snap. The bright annealing gas left the generating machine at slightly below 40° dew point and investigation showed that during cold weather, moisture condensed out of the gas in the distribution lines and collected at low points and pockets in the

piping. When the weather moderated this moisture was evaporated and added to that already in the gas, bringing the total moisture above the danger point. This source of moisture pick up can be remedied by sloping the distribution lines so that they drain to selected points where the moisture can be removed by blow offs or traps.

Considering methods of application, the injurious effects of damp brickwork, leaky covers and poor sand seals are so obvious as to require no comment. The rapid contraction of the gas inside the box during the early part of the cooling cycle requires a large supply of gas to maintain the required pressure within the box. The oxygen pressure outside the box is one-fifth atmosphere and the oxygen pressure inside the box is negligible. A total pressure appreciably above atmospheric inside the box is necessary to prevent oxygen diffusion into the box through sand seals, etc.

Methods of application are as important as gas composition and poor results are frequently due to wrong practice. In general, if results are consistently poor, the gas composition is at fault. If results are erratic, with some good and some poor product, the practice is probably at fault.

C. E. Peck: This paper serves a particularly useful purpose in that it emphasizes the desirability and need of a clearer understanding concerning the functions of protective types of atmospheres on steels of various kinds and the effects of impurities in the atmospheres.

The bright annealing of all types of steels requires, in general, an atmosphere either entirely free of oxidizing components or containing oxidizing components in relationship to one another such that their action is neutral with respect to the surface of the steel. We may define oxidizing components as follows:

1. Free oxygen.
2. Water vapor.
3. Carbon dioxide.
4. Carbon monoxide.

The writer's contact with bright annealing problems confirms, in general, the author's experience, that to successfully bright anneal stainless steel or heat treat silicon steels, an atmosphere in which the last traces of oxygen and water vapor are removed is absolutely essential to attain the best results. In other words, these types of steel require an atmosphere free of all types of oxidizing components as defined above. The types of gases available to meet these requirements are:

1. Dry pure nitrogen.
2. Dry pure hydrogen.
3. Dry pure dissociated ammonia.

Two remaining types of steels classified broadly as high carbon and low carbon do not in most cases require an atmosphere absolutely free of oxidizing components as long as these components exist in relationship to each other such that they do not react with the surface of the steel. Experience indicates that partially burned fuel or hydrocarbon gases may be used for these steels and obviously this type of atmosphere is much more widely used, since it is cheaper and more easily available commercially. The relationship between the oxidizing components which must exist to successfully bright anneal and prevent either carburization or decarburization cannot be predicted from a purely theoretical standpoint due to the fact that partially burned hydrocarbon gases are a complicated mixture of hydrogen, water vapor, carbon dioxide, carbon monoxide, uncracked hydrocarbons and nitrogen. In addition, each application of bright annealing calls for consideration of the following factors.

1. Type of fuel used for partial combustion.
2. Air to gas ratio at which fuel is burned.
3. Time and temperature at which work being heat treated is exposed to the atmosphere.
4. Consideration of extent to which auxiliary equipment is necessary to remove undesirable oxidizing components such as water vapor and carbon dioxide or undesirable impurities such as sulphur.
5. Type of furnace and quantity of atmosphere in contact with the work.

Because of the relatively large number of variables to be considered, it is easy to understand the author's statements that even though most mills have equipment for producing partially burned fuel gas atmospheres, there still can exist some confusion as to requirements necessary. This also explains the variation in results obtained in actual practice, and emphasizes the importance of a proper interpretation of the direct experience being obtained in this field.

As an example, the bright annealing of low carbon strip steel requires an atmosphere in which the balance between the amount of hydrogen and water vapor and the amount of carbon dioxide and carbon monoxide must be above certain minimum limits or discoloration and oxidation take place. Some operators have found that good results can be obtained without the necessity of auxiliary equipment such as refrigerators or dryers for water vapor removal. In a case of this type, the conditions encountered might show that low temperature cooling water is available all year or that the equipment used produces enough hydrogen in the combusted gas to minimize the need for extensive water vapor removal.

These factors, or a combination of both, may enable operators in one locality to do satisfactory work without equipment for water vapor removal, while operators in another locality could not turn out satisfactory work without the use of auxiliary drying equipment. Again, differences exist in the degree of bright annealing which is considered necessary with references to the condition and appearance of the surface which is defined as a bright anneal. Some manufacturers have all requirements filled with a bright annealed surface which other manufacturers could not use due to particular requirements in later processing which require plating, enameling, painting, etc.

R. J. McGuigan: Mr. Otis is to be congratulated on the presentation of this important subject in such a practical manner.

The bright annealing of continuous cold rolled sheets and coils is primarily a problem of control and requires:

1. Controlling a controlled atmosphere.
2. Controlling the application of this atmosphere.
3. Controlling the handling of annealing equipment.

A bright annealed sheet or coil is known to the sheet trade as a "Deoxidized Sheet" or "Coil".

At our plant, two controlled atmospheres are used for bright annealing of low carbon sheets and coils.

Coke gas is used in one unit and a partly burnt natural gas produced in a commercial "forming" apparatus in the other.

In using coke gas, the sulphur and moisture must be removed. The moisture content averages 9 grains/cu. ft. at the annealing boxes. The sulphur is entirely removed.

The partially burnt natural gas averages 4 grains of moisture/cu. ft. at the boxes. One important factor in successfully bright annealing sheets and coils is the temperature at which the gas is applied to the box.

Carbonization and decarburization is an important factor in many bright annealing processes carried on at higher temperatures but in sheets and coils this is only a minor factor because it is conducted at lower temperatures, 1250 to 1300° F. Also the solubility of carbon in ferrite is much lower than in austenite and carbon diffusion is minimized at this lower temperature which makes less active surfaces.

In the past, a familiar term and source of worry to high grade sheet manufacturers was "blue edges". But with the aid of present day modern equipment and the knowledge of atmosphere, a control practice can be established which eliminates this old problem of blue edges.

A. N. Otis: I am very glad to observe that the other speakers have confirmed, almost with unanimity, the conclusions that we have reached from our studies. It is true that practice has much to do with it, and it is also true that geographical location has much to do with it. In the southern states, and probably in the Pittsburgh area and West Virginia, where river water may be used for cooling, some sort of auxiliary apparatus for cooling the gas will probably be necessary. It is useless to spend money for it, however, when and where it is not needed.

In the last analysis, what we are really concerned with is the matter of oxygen pressure which Mr. Barnes spoke of, that is the partial pressure of oxygen.

I think perhaps you are all familiar with the old classic experiment of mercury and mercuric oxide. If you take a vessel of mercury, heat it, and introduce oxygen on the bath, by changing the oxygen pressure alone you can make mercuric oxide go back to mercury, and oscillate back and forth at will by changing the pressure. You can keep the oxygen pressure constant and by changing the temperature you can do the same thing. So that the equilibrium is really the relation between temperature and partial pressure of oxygen, but in our case it is combined oxygen, as CO, CO_2 and H_2O. It goes back to the fundamental laws which are the basis of the reactions, that is, the partial pressure of oxygen, and the partial pressure of oxygen must be kept low.

Air or free oxygen should be kept out of the gas, and out of the distributing lines and furnaces, as far as practicable. For some of the sensitive process referred to, none can be permitted, as already pointed out.

Association Activities

CHICAGO

February 15, 1938

"THE CIRCULAR SOAKING PIT"
By Sam F. Keener, President
Salem Engineering Company
Salem, Ohio

PHILADELPHIA

February 5, 1938

"RECENT ADVANCES TOWARD LIGHTNING PROOF TRANSMISSION LINES"
By Dr. S. K. Waldorf, Test Engineer
Pennsylvania Water & Power Co.
Baltimore, Md.

CLEVELAND

February 14, 1938

"ELECTRICAL EQUIPMENT FOR MODERN BLAST FURNACE SKIP HOIST"
By C. P. Hamilton
General Electric Company
Schenectady, N. Y.

BIRMINGHAM

February 28, 1938

"WARD-LEONARD CONTROL FOR STEEL MILL AUXILIARIES"
By L. A. Umansky
General Electric Company
Schenectady, N. Y.

PITTSBURGH

February 25, 1938

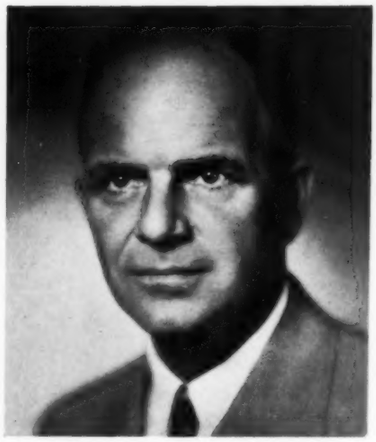
"AIR CLEANING IN THE STEEL MILL"

By H. P. Noles, Div. Sales Manager,
American Air Filter Company,
Louisville, Ky.

"Air Conditioning as related to Limiting Humidity in Iron & Steel Warehouses"

By C. W. Daubert, Engineer, Operating Dept.
Carnegie-Illinois Steel Corp., Pittsburgh, Pa.

The Use of



RALPH C. WALTER

▲ THERE has been so much general information given recently on the subject of extreme pressure lubricants that probably everyone has a fairly good general idea of the nature of such products and it will be unnecessary at this time to further discuss this feature. However, there still seems to be general lack of understanding of the various characteristics of these products and on the question of when and where they should be used. I would like to outline, as far as time will permit, present practices as developed over a period of actual steel mill operating experience starting with what I believe to have been the original major application of an extreme pressure lubricant to rolling mills and continuing up to the present time.

In this original installation one of the early 4 high continuous hot strip mills was revamped to roll wider and thinner gauge strip to meet the changing requirements brought about by new developments in the use of strip steel. In making this changeover the mill drives remained the same. The new and wider back-up rolls were equipped with new roller bearings of the largest size that could be fitted into the existing mill housings. Previous to the change the mill pinions had been lubricated with a good grade of so-called gear shield and the back-up roll bearings with a high grade roller bearing grease which at that time was approved for such applications.

When the revamped mill was put into operation the mill pinions almost immediately began to show signs of wear and cutting definitely traceable to a breakdown of the lubricant. A calculation of tooth pressures developed under actual operating conditions showed pressures in the neighborhood of 5,000 pounds per inch of face or almost double what the pinions originally were expected to carry. There was available at that time a product of the type now known as an extreme pressure lubricant with a film strength three to five times greater than that of the gear lubricants in general use and although this product had not been specifically designed for heavy industrial applications it was decided to try it out on these mill pinions. The results were very satisfactory, the cutting stopped almost immediately and the pinion teeth started to clear up.

This pinion situation was just getting under control when failures of the roller bearings on the back-up rolls began to develop. It was known that these bearings were operating at loads in excess of their standard rating and the failures were definitely lubrication failures. In view of the apparent success in overcoming the pinion troubles, the same roller bearing grease being used was compounded with the same extreme pressure agent used in the gear lubricant. This was tried out on the bearings and the results obtained were equally satisfactory, bearing failures from lubrication being completely stopped.

It was evident from these tests that lubricants were available which would hold up under the high tooth and bearing pressures developed in this type of mill. It only remained to further develop the products to specifically meet rolling mill conditions and to develop a technique for an extension of their application. The development of the lubricants was of course a matter for the laboratory technicians and we are concerned only with the development of the technique of their application.

Let us first consider the determining factors in the application of extreme pressure lubricants to the roller bearings for the roll necks, as this application is quite fully developed and can almost be considered standardized. As one of the primary functions of the roller bearing lubricant is to augment the mechanical seal in preventing the entrance of contaminants such as mill scale, water, etc., a grease is generally required. The consistency is determined by the type of bearing, speed, efficiency of the seal, temperature, etc., in general usign the lightest consistency practical. Load carrying capacity is of course the real determining factor. Load calculations are complicated and the only practical way is to take the manufacturer's specification that an extreme pressure lubricant of a certain load carrying capacity is required. The other specifications covering corrosion, water resistance, etc., must of course be met.

No special handling of this grease is required. The necessity of extreme cleanliness in handling anti-friction bearings and their lubricants to prevent the entrance of any dirt or foreign matter is so well understood that it is hardly necessary to stress the point. The use of a centralized automatic pressure system or a pressure gun for applying the lubricant is optional, the only requirement being an adequate supply of lubricant to the bearing. As an unusual temperature rise is one of the first indications of trouble in an anti-friction bearing, the installation of a thermo-couple in the back-up roll bearings, with recording pyrometer to give a continuous

EXTREME PRESSURE LUBRICANTS

By RALPH C. WALTER

Penola, Inc.

CHICAGO, ILLINOIS

Presented before the A. I. & S. E. Annual Convention, Chicago, Illinois, September 28, 29, 30, October 1, 1937

record of bearing temperatures, has in many cases resulted in the detection of trouble and permitted its correction where otherwise the bearing would probably have been completely wrecked.

Many operators find it good practice to take down these bearings at regular scheduled intervals, such as every 50,000 tons rolled, thoroughly clean them, inspect carefully, reassemble and fill with new grease. This extreme pressure grease when applied to the roll neck before mounting the bearing is quite effective in preventing scoring of the roll neck and the sticking of the inner race of the bearing on the roll neck.

There are two other bearing points on the 4 high mill where, in general, pressures developed definitely require an extreme pressure lubricant. These are the screw down screw and nut and the foot of the screw. In some mill designs the screw and nut are arranged for grease lubrication, in which case the same product as is used in the roller bearings can be applied. If a centralized system is used it is only necessary to provide additional outlets for these points. In other designs the screw and nut are lubricated from the bath which lubricates the screw down drive. As this drive requires an extreme pressure lubricant this works out quite simply. The foot of the screw is generally arranged for grease lubrication and can be hooked up to the centralized system.

Although this extreme pressure grease was developed primarily for large, heavy duty roller bearings it is definitely a general purpose grease, working equally well on either plain or anti-friction bearings and at speeds and temperatures generally encountered in mill operation. This characteristic offers many possibilities for simplified mill lubrication, particularly in conjunction with centralized pressure systems. There are today several mills operating with this single product on every grease lubricated bearing, plain, anti-friction, or sliding, from furnace table and slab return to coiler.

The simplicity of this practice more than offsets the fact that at certain points a different type of lubricant might be more specifically suited to the work. It also eliminates the all too frequent trouble arising from trying to apply the proper grease in the proper place when a variety of lubricants are specified for various points of lubrication throughout the mill. When a centralized system is in use careful consideration should be given to proper grouping of the outlets of the various central stations to prevent excessive application and waste of lubricant at points which only require lubrication at infrequent intervals.

The factors determining the use of extreme pressure lubricants in mill drives are of course loads and operating conditions, but for proper and economical lubrication these loads and operating conditions must be carefully analyzed to definitely determine whether they are necessary or whether the efficient yet low priced regular gear lubricants will handle the job. This can be done readily because approximate calculations are comparatively simple and loads under actual operating conditions can be readily checked.

For simplicity, let us take the individual factors entering into these determinations, although in most cases several of the factors are actually involved. First, we have the comparatively simple case where changes in product requirements or operation have increased the loads on existing equipment to a point where old methods of lubrication are resulting in drive failures. The original extreme pressure lubricant installation as previously outlined is an outstanding example. In such cases the necessary change-over to an extreme pressure lubricant is definitely required. The rapid advances made in recent years in the use of alloy steels as well as increased production demands have in general increased load conditions on the older mills and will probably continue to do so even on the mills recently installed. This of course applies not only to 4 high but also to all other type mills.

Next we have the case where structural limitations determine the size of drives. This applies principally to the pinions driving the work rolls of 4 high mills. Generally speaking, these pinions are limited in pitch diameter to the work roll diameter. Good design limits the face to not over twice the pitch diameter. Consequently these pinions, although limited in size, must transmit all loads which the mill motor is capable of delivering or which are required in the rolling of the strip. These loads may even approach the strength of the material in the pinion teeth. Operating and experimental data indicate that a good gear lubricant will satisfactorily maintain a protective film at tooth pressures up to about 3,500 pounds per inch of face. This figure is of course approximate and is subject to some variation dependent upon size of pinion, pitch of teeth, and velocity at pitch line. At pressures above

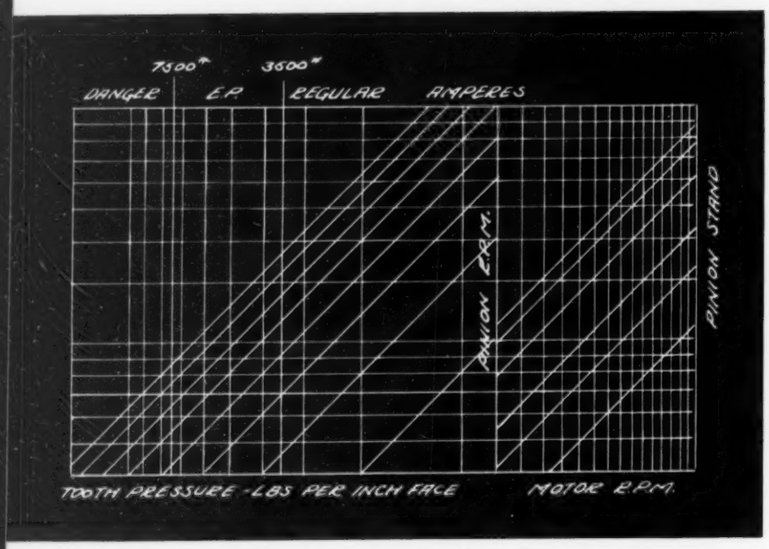


Figure 1—Graphical analysis of pinion load conditions of a 4-high mill.

this figure an extreme pressure lubricant is definitely required.

For a simple and quick analysis of pinion load conditions on any particular 4 high mill I use a graphical method as shown on Fig. No. 1. The typical 4 high mill is equipped with tachometers to indicate motor or work roll revolutions and ammeters to show motor loads. With a fixed pinion size, tooth pressures are directly proportional to the ampere load and inversely proportional to the revolutions. The chart is read in the following manner: The motor speed as shown by the tachometer is on the right hand scale. Reading vertically to the diagonal line for the pinion stand in question shows the pinion revolutions directly on the center vertical scale. Reading horizontally left to the diagonal line showing the ampere load will give the approximate tooth pressure in pounds per inch of face on the left hand horizontal scale. Using such a chart permits a quick and fairly accurate check on tooth pressures for any operating set up.

I have shown a dividing line at 3,500 pounds pressure per inch of face as the upper limit for safe lubrication with an ordinary gear lubricant. Between this point and another dividing line at 7,500 pounds is the zone definitely requiring an extreme pressure lubricant. Above this point pressures are approaching the limit of strength of the material in the pinions and definitely constitutes a danger zone. A protective film at pressures in this danger zone can only be maintained by a careful selection of a suitable grade of extreme pressure lubricant.

The dotted lines on Fig. No. 2 shows actual tooth pressures on three pinion stands of a typical 4 high strip mill using an average of typical mill settings. This already shows the definite requirement of an extreme pressure lubricant. Fig. No. 3 shows a similar typical set up on another mill. The low tooth pressures in this case indicate that an ordinary gear lubricant will be satisfactory.

There are in general no such structural limitations on the reduction gears between the mill motors and pinion stands so in general tooth pressures are lower and extreme pressure lubricants are not essential (although they are desirable, particularly during the "break in period" of a new gear drive).

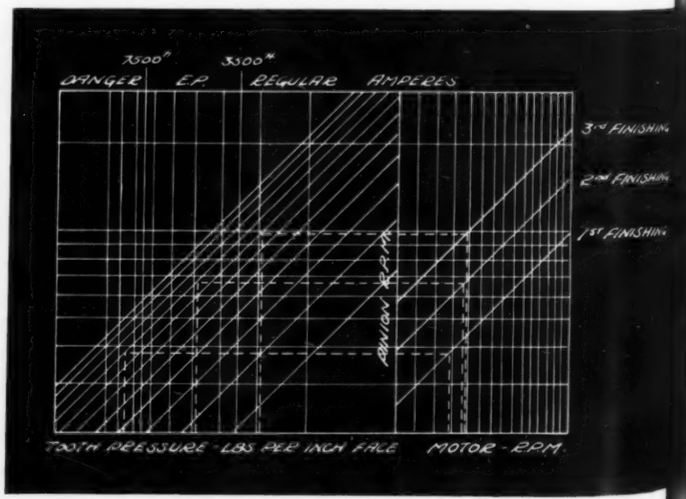
Fig. No. 4 shows the tooth pressures on the reduction gears driving the pinions of the mill shown on Fig. No. 2. These pressures, while near the upper limit for ordinary gear lubricants, are much lower than the corresponding pinion tooth pressures.

This development of the application of extreme pressure lubricants to the gears of mill drives has led many builders of drives to take advantage of the heavy load carrying capacity of these products and they are now designing drives utilizing a higher tooth pressure figure. This permits a more compact design of unit with a better load distribution on the gear teeth and more efficient bearings. The designer's specifications in such cases determines the necessity of an extreme pressure lubricant.

This covers in a brief and general way the application of extreme pressure lubricants to mill drives where tooth pressures alone are the determining factors. However, a unique characteristic of these products opens a field of applications which is perhaps broader than that covered by load considerations alone. This characteristic is its efficiency as a bearing lubricant. By using these products bearings will run as cool or cooler than with an oil of the same viscosity and in general they also carry the approval of the anti-friction bearing manufacturers.

We are all familiar with the more or less general difficulty experienced with mill drives using a gear lubricant on the gears and a lighter oil on the bearings, due to contamination. If the bearing oil leaks into the gear lubricant tooth protection is inadequate on account of a thinning out of the gear lubricant, and if the gear lubricant contaminates the bearing oil the

Figure 2—Actual tooth pressures on three pinion stands of a typical 4-high strip mill.



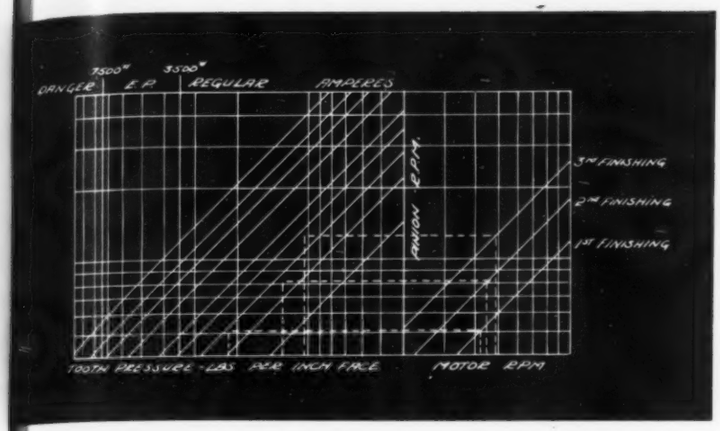


Figure 3—A setup similar to that shown in Figure 2. The low tooth pressures in this case indicate that an ordinary gear lubricant will be satisfactory.

bearings will run hot. An extreme pressure lubricant offers an ideal solution of this problem, for with its high film strength a viscosity light enough to suit the bearing clearances and speeds will still give adequate tooth protection as well as perfect bearing lubrication.

This very simple solution is being applied to many existing units where contamination trouble is being experienced and many manufacturers of mill drives are incorporating this unit lubrication feature in their design with uniformly excellent results. In some cases a group of units is supplied from a central circulating system with separate leads to the bearings, in other cases the lower housing of the unit is enlarged to act as a reservoir for the lubricant and individual pump provided to supply the gears and bearings or splash alone depended on, making each gear set an individual, self-contained unit. The simplicity of such installations is quite evident. In the case of pinion stands for extreme heavy duty service, it is generally necessary, however, to use different consistencies of lubricant for the gears and bearings, but the same self-contained unit construction can still be followed.

The extreme pressure lubricants for mill drives do not require any handling different from ordinary lubricants, but I would like to add a few suggestions for obtaining full advantage of their possibilities. Gear lubricants in general probably receive as little care and attention as any in mill use. In the past they have been of a heavy viscous nature, a development of the early days of open cast gears when tar was used as a lubricant. Little attention was paid to contamination and if they thickened up due to service or cold weather, steam was turned into the heating coils and the lubricant heated until the desired fluidity was attained. With the advent of circulating systems more care was given to lubricants but it is seldom we find the attention given these systems compares with that given lubricating systems serving such equipment as mill motor bearings or steam turbines.

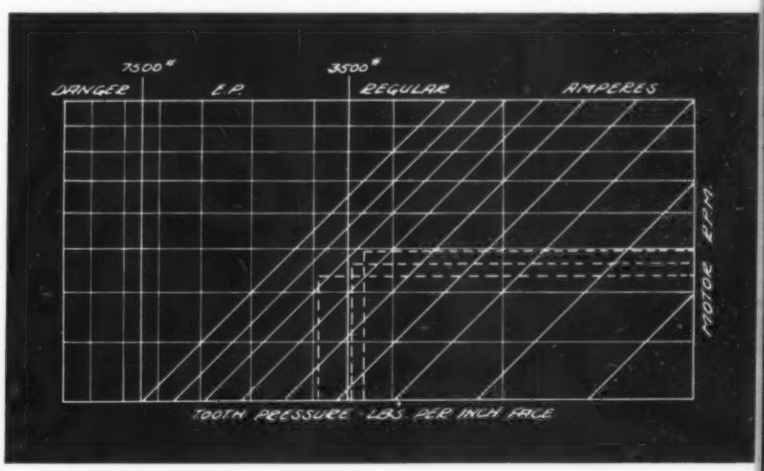
We are all familiar with the extreme care given the lubrication system of steam turbines. To be sure this equipment operates at high speed and the lubricant is subjected to high heats and water contamination but it is subject to a constant check for viscosity, acidity, sludge, etc., and is maintained closely to its original specifications or renewed. Many of the modern 4 high mill drives are subjected to loads far in excess of any on the turbines as well as contamination and extremes of temperature but the lubricant receives much less attention.

It has been quite difficult to overcome the old prejudice in favor of heavy viscous gear lubricants. While some progress has been made in a standardization of viscosities to suit size and speed of gears, nothing really definite is yet available. Experience seems to indicate that viscosities light enough to circulate freely at normal operating temperatures give the most satisfactory results. While extreme pressure lubricants have less variation in viscosity at different temperatures than the ordinary gear shields or gear lubricants, it is advisable where gears are operating at tooth pressures in the danger zone to provide cooling for the lubricant during the hot weather or when the drive unit is subject to heat radiation from the mill and to provide heating in the extreme cold weather in order to maintain the lubricant at its highest operating efficiency. The viscosity should be checked at regular intervals and the product adjusted to the proper viscosity.

In addition to this check the lubricant, if used in circulating systems, should be periodically filtered or centrifuged, the frequency depending upon operating conditions. We are frequently questioned about centrifuging. The answer is simply that in a proper extreme pressure lubricant the extreme pressure agent is incorporated in such a way that it cannot be mechanically separated. It must not be incorporated as a mixture or a filler but must be in what can probably best be described as a solution, although this term is not chemically correct. If incorporated in this manner the extreme pressure agent effectively resists separation when centrifuged.

Any filler, no matter how soft, will act as a lapping agent under extreme pressure operation; in fact it is more or less common practice in the field to add flowers of sulphur, zinc oxide, or other mild lapping agent to

Figure 4—Tooth pressures on the reduction gears driving the pinions of the mill shown in Figure 2.



the lubricant to smooth up surfaces roughened in service. I recall an extreme case where a filled lubricant was put in a set of pinions operating at tooth pressures around 5,000 pounds per inch of face and almost $\frac{3}{64}$ of an inch was lapped off in 60 days' time.

Another point which has been receiving considerable attention as these products come into more general use is the maintenance of a dry atmosphere within enclosed units. In many cases condensation within the gear case, particularly during week end shut downs in the winter, is sufficient to materially contaminate the lubricant. Certain manufacturers of drives are taking the necessary precautions to maintain the atmosphere in the unit below the natural dew point.

As far as circulating systems are concerned, the same general standards of capacity, pressure, quantity of flow, etc., apply for extreme pressure lubricants as for circulating oil systems. With these precautions being taken, full advantage of the extreme pressure lubricants can be realized and long life of the product assured.

Pinion and gear drives operating at high tooth pressures put an added burden upon the maintenance department. The manufacturer is furnishing drives with precision cut gears accurately aligned and lapped to perfect contact and they must be kept in this condition as nearly as possible. The alignment is of particular importance. Any deviation will, in general, affect the proper tooth contact. As the tooth pressure is inversely proportioned to the length of face in contact it is easy to imagine what may happen if the gears are already operating at pressures approaching the strength of the material. With a proper extreme pressure lubricant in use, with the gears in proper alignment and tooth pressures below the limit of strength of the material in the gears, I have never seen a gear failure from pressure alone. Misalignment seems always to be the basic cause when failure occurs under proper lubricating conditions. I might add that the worst pinion failure I have ever seen occurred on a set where tooth pressures under normal operating conditions did not exceed 1,000 pounds per inch of face.

Trouble shooting is always interesting work for a lubricating engineer and extreme pressure lubricants are particularly adapted to many troublesome jobs. Probably the simplest way to show the possibilities of these products for such work is to give a brief outline of several specific cases involving miscellaneous steel plant equipment. A main shaft bearing next to the flywheel of a plate mill shear drive ran so hot that it was necessary to keep a stream of water on it continually to prevent overheating. An extreme pressure lubricant was used in the sight feed oiler in place of the bearing oil and the bearing has run at normal temperatures ever since.

A worm gear driving the depressing table on a blooming mill shear was cutting badly. The worm gear lubricant was changed to one with extreme pressure characteristics. The cutting was stopped and a 30% power saving was noted on the motor drive.

The bearings of the sheaves which carried the cables for the boom and dipper counterweights on a very large electric shovel gave so much trouble that it was necessary to keep one man oiling them almost constantly. Bearing pressure figured excessively high and a change to an extreme pressure lubricant solved the problem.

The M.C.B. truck bearings on a large open hearth ladle crane were scoring badly. The usual practice of packing with wool waste and lubricating with black oil was being followed. The bearing loads were high and a charge from the black oil to an extreme pressure lubricant for saturating the wool waste immediately stopped all bearing trouble. This is now an accepted practice for heavily loaded packed bearings.

A 1,500 ton mixing ladle when put into operation had a jerky motion when being tilted. The trouble was finally diagnosed as a breakdown of the lubricant in the trunnion bearings and a change to an extreme pressure lubricant restored the smooth operation so necessary for this equipment. Extreme pressure lubricants have shown particular merit for large, heavily loaded bearings where in ordinary operation rotation is less than a full revolution.

In addition to these, there are numerous cases of trouble with machine tool drives such as large planers and boring mills which have been corrected by a change to extreme pressure lubricants.

There is no question that these lubricants have taken a definite place in steel mill operation and I feel that as the unusual characteristics of these products become more generally understood and their uses extended, new standards of efficiency and simplicity will result.

DISCUSSION

PRESENTED BY

C. R. HAND, Lubrication Engineer, Bethlehem Steel Company, Sparrows Point, Maryland.

C. H. JOHNSON, United Engineering and Foundry Company, Pittsburgh, Pennsylvania.

L. F. COFFIN, Superintendent, Mechanical Department, Bethlehem Steel Company, Sparrows Point, Maryland.

D. E. McGUIRE, Chief Draftsman, Great Lakes Steel Corporation, Ecorse, Michigan.

F. L. GRAY, Lubrication Engineer, Carnegie-Illinois Steel Corporation, Gary, Indiana.

C. R. HAND: The development and application of extreme pressure lubricants, as outlined in this paper, have been very interesting. It is clearly shown that they are of great value to the lubricat ing engineer in getting him out of trouble. Trouble may be poor design or erection, either original or, due to trying to make old mills over to suit new conditions. Unfortunately, these conditions are always present in all plants.

There is no question that the compounds used in extreme pressure lubricants do retard wear under those conditions. Heavy starting loads on gears and pinions as well as shock loads incurred during rolling, cause metal to metal contact even with the best of the extreme

pressure compounds and some wear results. Similar results may be expected from ball or roller bearings. Balls or Rollers will show surface defects which eventually cause destruction whether we have extreme pressure lubricants or not. Any mill that is stopped and started with load in the mill and screws tight has its bearing rollers and races slightly deformed, and when rolls begin to revolve, scuffing results. Certainly a load sufficient to deform the roll at all, is enough to break the lubricant out from between the surfaces.

The necessity of sealing bearings and gear cases against water and dirt is doubly important when extreme pressure compounds are used. All of the compounds mixed with the mineral oils and greases are salts of organic acids and readily absorb water. In most instances, the water destroys their value as extreme pressure lubricants. The control of the atmosphere in gear cases is almost impossible from a practical standpoint and few, if any, of the old mills could be changed to accomplish it. Water will and does get into all gear cases. In several cases on record, water has been the cause of serious shutdowns to clean out the systems, bearings and gear cases.

The use of thermometers in bearing cases should be more widely adopted on all rolling mills. This is the surest and quickest way to find damaged bearings or faulty lubrication. The size and inaccessability of modern design does not permit the old hand tests.

The regular inspection of bearings is of great importance. Modern rolling mill bearings, made with precision dies and jigs are worthy of the care given our turbines.

Mention is made that engineers are now designing gear drives to take advantage of the extreme pressure greases. Experience with drives tends to show that this is more of a hit and miss problem than an exact science. All drives for steel plant use should be designed with ample factor of safety and not with in the narrow limits necessary to use extreme pressure lubricants.

C. H. JOHNSON: Laboratory tests as well as tests made in actual service have without doubt demonstrated the exceptionally good lubricating qualities of extreme pressure lubricants. In his paper, Mr. Walter outlined specific instances where the substitution of extreme pressure lubricants resulted in entirely successful operation of certain machine parts whereas difficulties had previously been encountered with the use of so-called ordinary lubricants. Such occurrences are not uncommon, but we must remember that regardless of what lubricant is being used, care should be taken to keep it in good condition so that it will most efficiently serve its intended purpose.

As Mr. Walter pointed out, quite often, due to a change in operating conditions, a gear drive is called upon to transmit far greater loads than for which it was originally intended, resulting in abnormally high lubricating temperatures accompanied by excessive wear in the gear teeth. Many such instances have been encountered and very often steps taken to keep the lubricant at the proper operating temperatures have proven to be proper corrective measures even though straight mineral oils were being used; which indicates that the substitution of extreme pressure lubricants is not always the only solution to a lubricating and overload difficulty in connection with gear teeth. However, because of the load carrying characteristics of extreme pressure lubricants, more latitude may be allowed in operating temperatures with this type of lubricant than with ordinary lubricants of comparable consistencies.

The method of applying lubricants to gear teeth and bearings of gear drives is a very important item. The various methods used were briefly described by Mr. Walter. On small standard *stock* line reducers, such as being furnished the trade, a splash system is usually depended upon for lubricating gears and bearings. Such an arrangement is used for cheapness of construction. For the type of drive mentioned this design proves quite satisfactory as the speed range of the driving motor is usually such that the resulting peripheral velocity of the gears will distribute sufficient oil within the gear case to lubricate the bearings. On heavy duty mill drives, and especially those which operate on voltage control such as continuous strip mills and reversing mills, the motors are often operated at such low speeds that the peripheral velocity of the gears is not great enough to throw the oil into the channels directing it to the parts to be lubricated, resulting therefore in insufficient lubrication of these parts. On certain types of mills, the drives experience their greatest overloads when the mills are being started after a shut-down of considerable length of time. In such instances the driving pinion, or pinions if the drive happens to be a double reduction unit, may be required to make several revolutions under extremely heavy tooth loads before the splash effect carries any lubricant to the teeth. Similarly, the bearings may be insufficiently lubricated during the period in which the rotating parts are brought up to speed.

The positive, and quite inexpensive, method of lubrication for drive parts at all times and under any operating conditions is, of course, by means of a circulating system whereby the lubricant is supplied by sprays at the meshing points of the gears and fed individually to each bearing. Such systems have proven quite satisfactory with the use of either straight mineral oils or extreme pressure lubricants. In such systems the oil is allowed to settle out before being used over again and therefore renders it in a better condition when it is returned to the wearing parts of the drive. There is as much need for filtering or centrifuging the oil in a drive with splash lubrication as there is on a drive having a circulating system and there is no doubt that the filtering process can best be accomplished on the circulating system.

On installing a new drive, it is, as Mr. Walter mentioned, desirable ,if the additional cost is permissible, to use an extreme pressure lubricant on the gear teeth during the "Breaking-In" period. This breaking-in period is that time during which the teeth in the gear are being "work" hardened while operating with, in nearly all cases, a much harder pinion.

L. F. COFFIN: While recognizing the many proper applications of extreme pressure lubricants, the tendency to extend their use in main drives, should be combatted by purchasers and users of mill machinery.

To suggest that these drives should be designed with the idea of using such lubricants is only to invite main-

(*Please turn to page 63*)

Steel Mill

O. L. MAAG

▲ PROPER bearing maintenance is essential to secure maximum life and performance from equipment. To secure this, the engineering, production and mechanical departments must cooperate.

When preparing the original specifications for equipment, the engineering department analyzes each unit, determining the cycle of operation, loading, speed and operating conditions. On the basis of these factors the bearings are selected and provision made in the design for proper maintenance. Assembly and disassembly, inspection and lubrication are all studied.

The need for heavy maintenance, or the freedom from heavy maintenance charges is affected by the way in which equipment is used. Improper loading and abuse by frequent over-loading shortens the life of bearings and equipment. Warning signals and recording devices which register loads and temperatures are of value in guarding against such conditions.

Regular inspection and lubrication schedules should be established by the mechanical or maintenance department. This department should consult with the engineering and operating departments, making recommendations as to changes in design or operation which will reduce or facilitate proper maintenance.

It is the function of the bearing manufacturer to see that the bearings selected are properly designed and that provision is made for proper handling in assembly and disassembly and that they can be effectively lubricated and inspected with a minimum of trouble.

Lubrication plays an important part in the modern rolling mill, which is a complex organization offering the lubrication engineer perhaps a wider range of problems than any other industry. All degrees of speed are encountered and loads range from light to extremely heavy. Wider temperature variations must be handled and water, dirt and scale still further complicate the situation.

In the case of anti-friction bearings, the lubricant must act to: (1) Still further reducing the already slight internal friction in the bearing. (2) Dissipate heat. (3) Aid in keeping out foreign matter such as water, scale, etc. (4) Prevent rust and corrosion.

Heat in an anti-friction bearing may be due to a number of causes. If the bearing is over-loaded, distortion of the races and rollers as they enter and leave the load zone may cause a serious rise in temperature. The use of too much, or the wrong consistency of lubricant may cause a rise in temperature. In some cases, the surrounding atmosphere may reach a temperature actually injurious to the bearing, due to poor ventilation, etc. However, it is fundamentally the function of the lubricant to dissipate the heat and protect the bearing.

In some steel mills it is expected that the lubricant will aid in keeping foreign matter out of the bearings. This of course is mainly done by the closures, but the use of the correct kind and grade of lubricant will make the problem easier and the whole operation more efficient. When the lubricant is expected to function in part as a seal to prevent the entrance of foreign matter, it is essential that the proper consistency for the particular application be selected. Special emphasis should be given in this case to the requirement that the lubricant should not thin out too much in service.

The highly polished steel surfaces of anti-friction bearings are easily attacked by rust and corrosion, and the lubricant must prevent this attack, thereby maintaining the smooth surface so essential to friction-free operation. During shipment and in storage, bearing surfaces are carefully protected with a petrolatum or oil coating; after installation it is the function of the lubricant to maintain a rust and corrosion proof coating on the operating surfaces at all times. In this connection it is well to add a word of caution to operating men, and that is to watch their lubricants and see that they are always up to specifications for their intended applications. The laboratory can be of great value to the operating or maintenance department in this connection.

We probably will always have with us the man who says "If a little is good a lot is better". This is as great a fallacy in bearing lubrication as it is in medicine or anything else. If too much or too heavy a lubricant

LUBRICATION and LUBRICANTS for ANTI-FRICTION Bearings

By O. L. MAAG

Lubrication Engineer

The Timken Roller Bearing Co.

CANTON, OHIO

Presented before the A. I. & S. E. Annual Convention, Chicago, Illinois, September 28, 29, 30, October 1, 1937

is used there is bound to be some increase in temperature when the machine starts, usually followed by leakage. An attempt to stop this by tightening the closures will increase the friction, thus still further aggravating the condition until in extreme cases the bearing fails.

Since temperature affects the viscosity of a lubricant and therefore its film strength, it is essential that we keep the bearing and lubricant as cool as possible. This can be done by preventing churning, by using as large a volume of lubricant as is consistent with good practice, by installing water jackets around the bearing, or by passing the lubricant through a cooling system. When steel mill bearings and lubricants are maintained at a uniformly low temperature, operators find that it is easier to maintain uniformity in gauge and quality of the product being rolled and likewise that the lubricant does not break down as quickly, and lasts longer.

High temperature conditions are likely to cause foaming and separation of soap and oil, particularly when the grease has a high moisture content. The oil may drain out, leaving only the heavy soap in the housing. When this occurs, the lubricating value of the grease is seriously affected and it is advisable to clean out the bearing and housing and start over, using just enough grease. It is quite likely that in the near future all operators will insist upon having a grease that is practically moisture-free, permitting less than 1% of water.

When it is known that a bearing will be subject to high temperature under operating conditions, special lubricants should be used. Greases for use under these conditions should be of such a character that they will return to their original consistency, when the bearing cools, with practically no separation.

Likewise, unless proper care is used in selecting the proper lubricants the reverse condition may be encountered in cold weather. If the lubricant will not flow, the bearing rollers or gears will merely cut a channel through the stiff oil or grease. This is particularly serious when bearing lubrication is dependent upon splash from the gears. In certain cases this difficulty can be overcome by making provision for the installation of a steam coil to thin the lubricant in cold weather. This, however, is frequently difficult to do. Consequently, special thought should be given to the selection of the lubricant best suited to the conditions that will prevail without the use of special heating devices.

If the grease in a bearing is not renewed for a long time, a deposit of lime or soda soap may form in the housing, reducing the space available for the effective lubricant and at the same time tending to insulate the housing and reduce heat dissipation. Proper attention to lubrication will of course prevent such an occurrence. And finally, there is the situation which develops when a grease is used that is too heavy to flow into and around the bearing. When this occurs and the bearing has not entirely failed, we find it discolored even though there may be plenty of grease in the housing. The heat had melted the stiff grease before complete failure occurred and caused it to flow in and cool the bearing. Such a condition usually requires the replacement of the bearing, but should never be permitted to occur.

Thus the precautions necessary to assure proper lubrication will be seen and we will move along to discuss the types of lubricants most frequently used in steel mills, the way in which they are ordinarily used, and the specifications which have been developed.

Practically all lubricants now used, both oils and greases, are either straight petroleum products or are compounded from petroleum products. Oils range from the light, non-viscous bodies on down to the heavy cylinder stocks. Greases likewise cover a wide range, including both lime and soda soaps, aluminum stearate, lead base, and mixed basic compounds. To these lubricants must now be added the "EP" or extreme pressure types, developed for heavy duty during the past few years.

Steel mill equipment frequently includes high speed units where oil lubrication is desirable. Ordinarily such equipment carries a comparatively light load, but the high speeds have a tendency to develop over-heating unless light-bodied oils are used. Sight feed, constant level, and wick feed oilers are commonly used on equip-

ment of this nature, the last two being the most economical, although for certain types of equipment the accuracy and positive assurance of lubrication given by the sight feed oiling system makes it preferable. With the sight feed oiling systems, oils compounded with from ¼% to ½% of soaps adhere better to the bearing surfaces and feed more slowly, affording a degree of economy worth consideration. Recent work along this line has indicated that partially oxidized oils and certain of the newly developed chemical compounds and oiliness products have shown merit.

Circulating oil systems offer a number of advantages in lubricating gear drives and the bearings connected with them, cutting equipment, automatic machines, etc. Such systems, however, operate best with straight well refined petroleum lubricants.

The outstanding advantages of a circulating system are: (1) Ample lubrication. (2) The circulation of the oil through the bearing has a cleansing action, washing out any impurities or foreign matter that might be present. (3) There is practically no churning of the lubricant in the bearing, hence, with the minimum amount of lubricant present, lower operating temperatures are generally secured. (4) With a circulating system it is possible to provide for settling, filtering or centrifuging the lubricant. In case the lubricant has a tendency to become warm, it is possible to cool it separately, thus keeping the system supplied at all times with clean, cool lubricant. (5) The cooler operating conditions will reduce the oxidation or breaking down of the lubricant and thus increase its life.

Gears and anti-friction bearings are often lubricated with the same lubricant. In this case, a mineral oil that is satisfactory for the gears is usually entirely satisfactory for the anti-friction bearings. In quite a few cases, however, in order to take care of the gear units, it has been found necessary for good operation to use an extreme pressure lubricant of approximately 90 to 150 seconds viscosity at 210°F. Such a lubricant should carry a minimum load of 33 pounds on the Timken Lubricant Tester.

It is essential that the mill operator make sure that the lubricant being used does not contain any corrosive or abrasive material. This is particularly essential when any copper bronze bushings are lubricated by the same EP lubricant as is used for the gears and anti-friction bearings. Some of the EP hypoid lubricants contain an active sulphur compound and we have found as high as three tenths of one percent of copper in a sample of used lubricant taken after approximately two weeks service from a hypoid gear housing in which copper bronze bushings were used.

Likewise, when a circulating oil system is used, it is important that the lubricant, particularly if it is of the EP type, be free from materials which will emulsify in the presence of water and scale. Any emulsions will be thrown out by the filtering or centrifuging equipment which is usually part of a circulating oil system and there is danger that the load carrying capacity of the oil may be dangerously reduced without warning when a lubricant of this type is used.

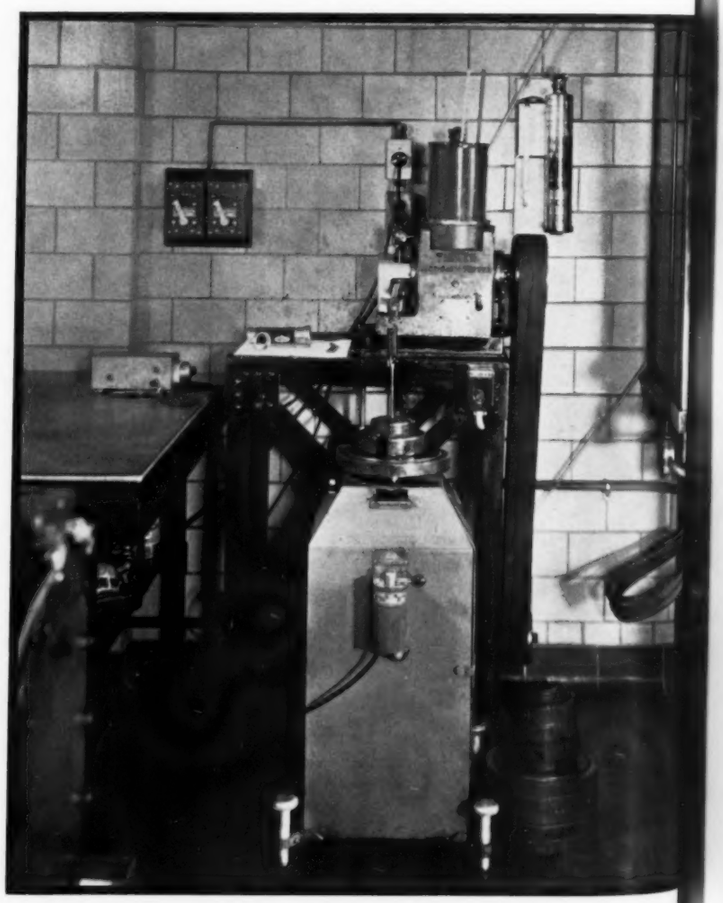
The types of extreme pressure lubricants with which the Timken Company has had success on gear units are those having a lead soap sulphur base, a chlorinated sulphur base, the straight chlorinated base compounds and phosphorous compounds.

For table rolls, etc., encountered in rolling mills, the type of lubricant is largely dependent upon the design of the closures. If the closures are tight, fluid oils are entirely satisfactory and when this type of lubricant can be used, we prefer to recommend it.

Due to the design of equipment and the conditions under which it must operate, grease is widely used. Various types of greases are available and care should be exercised in their selection. Lime soap products are ordinarily lowest in price and have the widest use. As they are not particularly affected by water, these greases as well as those compounded with aluminum stearate are widely used for lubricating equipment where moisture may be encountered and where operating speeds are comparatively low. High operating speeds and high temperatures, but without the presence of moisture, call for the use of soda soap lubricants as a general rule, since their melting point is higher.

In all cases where grease is used as a lubricant, it is essential for best results that ample space be provided in the housing, yet not so much room that the action of the bearing will throw the grease against the walls of the housing too far away for it to flow back readily into

The Timken Lubricant Tester, equipped with the latest automatic machine loading device, is a simple machine for measuring the film strength or load carrying capacity of a lubricant.



the bearing. Occasionally slow speed conditions will be encountered where it is essential that the housing be kept full of grease, but these conditions are rare and require close watching. Normally, however, the housing should not be filled more than half full. This permits the grease to expand without being forced past the closures, avoids churning and assures adequate lubrication without waste.

When applying grease to a bearing, particularly for the first time, special care must be used to see that it is applied directly to the bearing and not merely placed in the housing. Provision should always be made so that over-zealous workmen cannot apply too much lubricant to anti-friction bearings in their routine greasing operations, for the reasons previously mentioned. Many housings are now provided with lubricant overflow outlets to control the amount of lubricant present.

There can be no question but that EP lubricants are here to stay, and it is practically safe to say that most greases of tomorrow will be of that type. Even though many mills now equipped with Timken Bearings are successfully using standard greases, the newer ones are using extreme pressure lubricants. Bearings of course must be designed with due regard for the type of lubricant to be used, for some extreme pressure lubricants as compounded today have a tendency to cause abrasion or corrosion unless proper precautions are taken. However, under present day operating conditions, no one can tell when some mill operating condition will cause over-loading and consequently The Timken Roller Bearing Company now recommends the use of extreme pressure lubricants for all types of bearings in steel mill heavy duty service.

We have not found it necessary to restrict the grease manufacturers to any special type of compounding in making EP greases for steel mill service. In general, however, cold worked or milled grease should be used to avoid the possibility of the lubricant thinning out too much in serice. Experience to date indicates that the various types of sulphur-saponifiable, lead-soap-sulphur, chlorinated and phosphorous types or combinations are satisfactory when properly compounded.

Dark greases seem to be in better demand for steel mill use, although there seems to be no technical reason for this preference. In that connection, however, it should be remembered that dark greases do not indicate by a change in color the presence of contamination by water or dirt.

Some greases have the ability to hold considerable water before thinning out too much, which at times is a desirable feature. The average lime soap grease used in steel mills will emulsify with between 20% and 25% of water, any additional water appearing in the form of free globules. The degree of thinning varies with different greases, some becoming very thin with the same amount of water that apparently does not seriously affect other types. This free water is chiefly responsible for etching or corroding bearing surfaces. Operators may expect some trouble from emulsification and scale even when using EP greases. However, since water, and grease containing water in the form of an emulsion, is lighter than fresh lubricant, the periodic addition of new grease will serve to force the thinner material out of the bearing. This re-coats the bearing surfaces with fresh, dry lubricant and avoids serious difficulties. Provision should therefore be made in the housing or closure design to permit the removal of emulsified or contaminated grease while fresh lubricant is added either from a centrally controlled pressure system or from a pressure gun.

In the selection of lubricants the bearing size, speed, temperature, load and general operating conditions must all be considered, with the most adverse conditions being chosen as the governing factors. For example, in applications using bearings not over 6 inches in outside diameter and operating at a speed of less than 1000 RPM with no unusual service conditions, either a lime or a soda soap grease of medium to medium soft consistency should be recommended. With the same set of conditions prevailing except that moisture is present, only a grease with a lime base would be satisfactory.

At speeds above 1000 RPM, oil is considered more satisfactory than grease, although on the smaller size bearings grease is successfully used. For bearings over 6 inches in outside diameter, medium consistency and medium to soft consistency greases are only recommended up to speeds of 500 RPM. Oil is considered as the better lubricant at speeds above 500 RPM.

Conditions of high operating temperature require special recommendations. A lime base grease will usually tend to melt at approximately 150-175°F. It therefore cannot be approved for higher temperatures. Soda base greases will usually hold up to over 200°F., and are therefore more suitable for the higher temperature applications. Above 200°F., better results are generally secured by using an oil having a viscosity of 100 to 200 seconds Saybolt Universal at 210°F. Steam cylinder oil of the proper degree of refinement for the requirements can be obtained from any reliable oil company.

Bearings exposed to extreme cold are best lubricated by an oil with a low viscosity and low cold test. A highly refined mineral oil with a viscosity of 75 to 500 seconds, Saybolt Universal, at 100°F. is recommended, depending upon the application.

It is realized that considerable work still remains to be done in the development of various types of lubricants to meet the advancing needs of anti-friction bearings. The Timken Roller Bearing Company is constantly conducting tests on suggested products and cooperating with oil and grease manufacturers in an endeavor to solve the needs of the various fields in which Timken Bearings are used, and welcomes any suggestions as to work to be done along these lines.

DISCUSSION

PRESENTED BY

HERMAN BERRY, Engineer, Carnegie-Illinois Steel Corporation, Gary, Indiana.

H. BERRY: Mr. Maag is to be commended for his splendid paper and I want to express my appreciation for his work in steel mill lubrication. His statement that "the freedom from heavy maintenance charges is

affected by the way in which equipment is used" cannot be too strongly emphasized to all steel mill maintenance departments. Improper loading of bearings together with little or no lubrication, causes losses each year amounting to thousands of dollars.

I have recently observed large brass roll neck and pinion bearings of the sleeve type which have worn out completely in from two to six weeks, and in some cases the damaged bearings have been left in operation until the bearing blocks were so badly worn that entire new blocks had to be put in along with the bearings. Excessive wear and bearing failure can usually be traced to lack of lubrication and presence of scale, water and other foreign material. If the proper lubricant is being applied, lubrication will fail if the lubricant does not enter or is not fed properly into the bearing, or if the proper lubricant film cannot be established or cannot be maintained once it has been established. Elimination of most of the causes of bearing failure can be accomplished by substituting automatic lubrication in the place of manual lubrication, by the use of extreme pressure lubricants in cases of excessive bearing pressures, by protecting the bearing from mill scale and other foreign material, and by giving the proper attention to design of the bearing.

Mr. Maag has very ably presented most of the precautions necessary to assure proper lubrication, but before going further I would like some information on "viscosity of an oil" versus its "lubricity or oiliness". Mr. Gruse, in his works on Petroleum and Its Products, indicates that the viscosity of a lubricant is probably dependent upon the chemical and physical constitution of the lubricant, and Herschel states that "oiliness may cause two lubricants to give different coefficients of friction when their viscosities at the film temperature and all experimental conditions are the same". In view of these statements, do lubricants made from some crude oils have any apparent advantage in load-carrying properties over other lubricants made from different crudes? And if so, can the advantage be attributed to the specific property of "oiliness", rather than to differences in viscosity—temperature relationships?

Also, I should like to ask Mr. Maag about the possibility of testing the "oiliness" of lubricants by a simple block and inclined plane tester? In this method of testing the adjustable plane would be lubricated, inclined at the desired angle, and the test block allowed to slide down the lubricated incline. All frictional surface would be accurately machined and thoroughly lubricated. Lubricants would be tested at room temperature and their corresponding viscosities determined from the A.S.T.M. Standard Viscosity-Temperature Chart. After a number of tests a simple coefficient of fluid friction-viscosity chart could be made for each lubricant tested. It seems to me that such an instrument would provide a fairly accurate test of the oiliness of nearly all oils and could be used to a good advantage on most greases.

The question also arises in my mind as to the advisability of using one extreme pressure lubricant in an oil circulating system to lubricate both the gear set and anti-friction bearings. In view of the fact that many of our present day oil circulating systems contain centrifuging equipment, and in light of Mr. Maag's warning concerning the possible dangers from corrosive or abrasive material in some extreme pressure lubricants, is it ever advisable to adapt one E P lubricant to both the gears and the bearings?

O. L. MAAG: Mr. Berry wishes to know if a lubricant made from one crude oil has greater load carrying capacity than one made from another. In answer to that I would say that there are indications that a well-refined high viscosity index oil would carry slightly more load than a low viscosity index oil due to the fact that a low viscosity index oil thins out more rapidly with a rise in temperature and therefore reaches a breaking point before the high viscosity index oil. This would not necessarily be true; however, if these were extreme pressure products naturally in the crude. We have tested a motor oil made from a high sulphur "Smackover" crude that contained over 2% sulphur which had about double the film strength of a Pennsylvania grade motor oil of the same body, when tested on the Timken Testing Machine.

Oiliness, as I understand it, is different from film strength, although an addition agent may give rise to both when added to an oil. Of two oils having the same viscosity at the operating temperature of a bearing, the one that produces the lowest friction is the one having the highest oiliness content. Some fatty oils, fatty acids, and other addition agents when added to mineral oils produce this property.

Mr. Berry speaks of determining the oiliness of a lubricant on a block and inclined plane tester. From experience we have had with this type testing I do not feel the method would be accurate enough as slight variations in the amount of lubricant as well as small temperature variations would prove the method valueless. As for grease, I feel that the slight working of them which causes a change in consistency would make it impossible to check results.

He also speaks of the advisability of using an extreme pressure lubricant in a circulating system for both gear and anti-friction bearings. This practice is being followed with success in a number of cases. The correct type extreme pressure lubricant should, however, be used for the operating conditions encountered. In gear cases with splash feeds for the bearings all types of stable extreme pressure lubricants are giving satisfaction. Where the lubricant must pass through a centrifuge before being returned to the gears and bearings, the compounding in the lubricant, which produces the extreme pressure properties, must not be thrown out by the centrifuge. We know of cases where lead soap lubricants when dry are satisfactory, but when moisture, either by condensation or physically got into the lubricant the soaps were thrown out by the centrifuge. We would recommend that the lubricant be tested with and without moisture in a centrifuge before installing it in a system.

WALTER DISCUSSION

(*Continued from page 57*)

tenance troubles. Low friction, low wear, better separation from water and impurities can be secured by avoiding the use of extreme pressure lubricants provided design of gearing, quality and hardness of gears and accuracy of tooth contour including sufficient lapping in, have been given sufficient attention.

D. E. McGuire: It has been a pleasure to have read the excellent papers presented by Mr. Maag and Mr. Walter, and I wish to thank Mr. Brent Wiley for the opportunity of reviewing these papers prior to this meeting.

The field of lubrication is so broad that any one of the many points brought up in these papers could be made the basis of detailed discussion which our limited time does not permit. However, a brief outline of the views and experience of a steel mill engineer in the field of lubrication may be of some interest.

Our work has been chiefly construction, involving the laying out, designing, and installation of mill equipment, and so far too little time has been given to a serious study of lubrication problems.

We, as a general rule, rely on the recommendations of the equipment builder and lubrication engineer for the proper type of lubrication to be used on this equipment. We then proceed to lay out and design the most efficient method of supplying this recommended lubrication, whether it be oil or grease, to the equipment. Since practically all types of lubrication are employed in the modern steel mills, from the manual to fully automatic application of greases and from the oil can to the highly specialized recirculating oiling systems, our experience has been quite varied.

We have found that our reliance on the experience and judgment of the mill builder and lubrication experts has been uniformly successful. There have been some instances when it has been found necessary to change the type and specifications of the lubricants over the original specifications when trouble developed due to improper lubrication. Also it has been found necessary to change or redesign bearings when changes in the lubricant failed to achieve the desired results. These instances of failure have been rare indeed.

From a study of the history of specialized lubrication, it is observed that a great deal of the progress made in this field has been the results of laboratory experimental work by companies whose chief interest is the sale of lubricants. I have vivid recollections of laboratory work and thesis writing at school, all of which was then financed by some oil company.

The many failures that have occurred in the past from a lubrication standpoint, I believe, have been largely due to the difficulty of properly interpreting this laboratory test data. The conditions met in practice can rarely be reproduced in the laboratory, and first determining what happens in service and then varying the laboratory tests until results are obtained which are similar to those found in actual service is of utmost importance.

The hundreds of mills scattered over our Country are the best field laboratories that could be devised, and it would be of immeasurable value to make available the wealth of information and data apparently hidden away in the minds and notebooks of the men who operate and keep the hundreds of mills running.

It has occurred to me and is offered as a suggestion that our Society magazine devote some space in each issue for the purpose of permitting operating men to disclose some of their lubricating experience, whether it be troubles or advice, to someone in difficulty. Lubrication problems which may be causing headaches for one group of men may have been successfully solved by others, and I believe that human problems, whether they deal with lubrication or not, are of great interest.

F. L. Gray: Mr. Walter has presented his paper in a very able manner. His discussion of the extreme pressure medium as applied to grease is worthy of attention by all plant lubrication engineers.

Our first experience with this type of product was on a head roller located in a 28″ rail stand. The roller was 24″ x 4″ with necks 8″ in diameter and 4″ long. The problem was one of speed, pressure, shock, water, heat, and scale. Several types of bearings and greases were tried with mediocre success. A roller bearing was finally used with a grease carrying extreme pressure characteristics. The combination of the bearing and grease eliminated our previous difficulty.

The basic idea of using a lead soap in an oil or grease is not a recent innovation. We are all familiar with the ancient practice of using white lead and cylinder oil on screws. In fact as far back as 1877 a patent was granted to Mr. E. E. Hendrick for the manufacture of a lubricating compound which contained equal parts of white lead and whale oil and was diluted with a mineral oil to the desired consistency.

Another patent was issued in 1907 covering the compounding of lead, animal fat, and mineral oil. In 1926 a patent was granted which modified the previous ones by using oleic acid and lead oxide.

We are indebted to the grease manufacturer for his research, and development of these basic ideas in order to bring us a product that has been outstanding in the solving of some of our most difficult problems of lubrication.

Mr. Walter stated "although they (E. P. Lubricants) are desirable, particularly during the break in period of a new gear drive."

We have been cautioned in years past not to apply extreme pressure lubricants to points where they are not needed. In fact we were warned that a great deal of damage could be done. This was true quite a number of years ago. It is my understanding that lead oleate or the more recent lead napthanate, when properly manufactured being free from lead oxide and foreign material will carry the extreme load without being abrasive.

Mr. Walter's statement would lead us to believe that the abrasiveness of the product is still present.

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J. M. MCCOLLOCH,
Sheet Mill Superintendent,
Otis Steel Company,
Cleveland, Ohio.

ASSOCIATION OF IRON AND STEEL ENGINEERS

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V. S. Acton,
Salesman,
Westinghouse Elec. & Mfg. Co.,
Chicago, Illinois.

Martin J. Anderson,
Chief Engineer,
Mathews Conveyer Company,
Ellwood City, Pa.

J. H. Bode,
Vice President,
Youngstown Foundry & Machine Co.,
Youngstown, Ohio.

M. J. Boho,
Sales Engineer,
Hagan Corporation,
Pittsburgh, Penna.

G. A. Broden,
President,
Broden Construction Company,
Cleveland, Ohio.

Geo. C. Davis,
District Manager,
The North American Mfg. Co.,
Chicago, Illinois.

J. A. Duchene,
Sales Engineer,
Mesta Machine Company,
Homestead, Penna.

Bradley B. Evans,
Sales Representative,
Erie Malleable Iron Company,
Erie, Penna.

K. C. Gardner, Jr.,
Engineer,
United Engineering & Foundry Co.,
Pittsburgh, Penna.

Richard C. Goss,
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Ohio Brass Company,
Pittsburgh, Penna.

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Vice President,
Continental Roll & Steel Foundry Co.,
East Chicago, Indiana.

F. B. Jones,
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Equitable Gas Company,
Pittsburgh, Penna.

Dan Lewis,
Manager Roll Dept.,
Continental Roll & Steel Fdry. Co.,
Pittsburgh, Penna.

R. C. Lewis,
In charge Rolling Mill & Acces. Equip. Sales,
Farrel Birmingham Company,
Ansonia, Conn.

Ralph G. Lockett,
Application Engineer,
I-T-E Circuit Breaker Company,
Philadelphia, Penna.

Louis F. Meissner, Jr.,
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Pittsburgh, Penna.

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Sales Manager,
Yale & Towne Mfg. Company,
Philadelphia, Penna.

Clarence J. Moore,
Sales,
Electric Storage Battery Co.,
Pittsburgh, Penna.

Clyde E. Orwig,
Sales Engineer,
General Electric Company,
Youngstown, Ohio.

Ernest M. Rase,
Mechanical Engineer,
Treadwell Engineering Co.,
Easton, Penna.

P. H. Reynolds, Jr.,
Chief Engineer,
Fischbach & Moore, Inc.,
Dravosburg, Penna.

F. Gordon Ricker,
District Manager,
Yale & Towne Mfg. Co.,
Pittsburgh, Penna.

George F. Russell,
Sales Engineer,
Muller & Harper,
Pittsburgh, Penna.

B. F. Schuchman,
Vice President,
Homestead Valve Mfg. Co.,
Coraopolis, Penna.

W. H. Seaman,
Vice President,
Mesta Machine Company,
Pittsburgh, Penna.

A. A. Morris,
Service Engineer,
Shell Petroleum Corp.,
Akron, Ohio.

J. S. Smith,
Factory Representative,
Wagner Electric Corp.,
Pittsburgh, Penna.

Kenneth A. Staats,
District Manager,
Pyle-National Company,
Pittsburgh, Penna.

Chas. H. Tate,
Sales Engineer,
Hagan Corp., Northern Equipment Co.,
American Arch Co.,
Cleveland, Ohio.

Henry A. Vanhala,
District Manager,
The Bristol Company,
Birmingham, Alabama.

S. R. Willock,
District Manager,
Treadwell Engineering Co.,
Pittsburgh, Penna.

E. M. Wise,
District Manager,
Alliance Machine Company,
Pittsburgh, Penna.

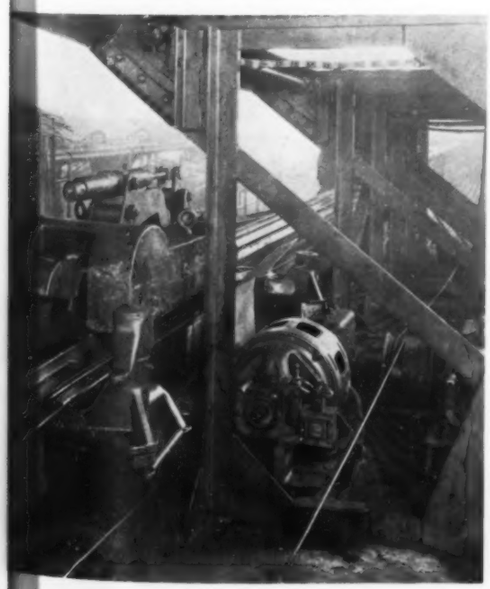
"I'LL TELL THE WORLD — BUSS FUSES SAVE US TIME AND MONEY!
THIS IS A
CONGOLEUM
GOLD SEAL RUG
SATISFACTION GUARANTEED OR YOUR MONEY BACK
KEIL
BUSS

APPEARING PAGES REMOVED

ALTERNATING-CURRENT MOTORS APPLIED TO MACHINE CUTTING COILED SHEET STEEL

▲ Alternating-current motors designed specially for the severe duty of sheet-catcher service a few years ago were recently applied with beneficial results to a machine for cutting coiled sheet steel to exact lengths and widths for fabrication, a machine that previously has used only direct-current motors. Without any sacrifice in quantity or quality of cut sheet the change resulted in a first cost only one-third of usual, power savings due to the elimination of conversion losses, and reduced maintenance because of the simpler alternating-current motors and control as compared with direct-current equipment. For a fabricating company where the tonnages and sheet gages are moderate like that used by the H. H. Robertson Company, Pittsburgh, for whom the Aetna Standard Engineering Company built the first unit; this alternating-current, Westinghouse powered shearing line gives results entirely satisfactory.

Alternating-Current motors applied to a machine cutting coiled sheet steel.



The machine takes a tight coil of hot rolled strip steel as it comes from the steel mill, processes and flattens it by passing it through multiple roll backed up leveller and sends it to a trimmer where first the ends and then the sides are cut without camber, in lengths up to 24 feet and widths of 18 to 38 inches with less than $\frac{1}{16}$ inch variation in dimensions. The sheet is fed to the machine at 150 feet per minute for cuts longer than 10 feet, and can deliver from 75 to 120 tons of squared, levelled sheet in eight hours. The uncoiling leveller is driven by a 60-hp., 870-rpm. squirrel cage motor; and the shear by a 450-rpm. induction motor designed to have low inertia.

Another steel working problem was solved in a somewhat similar fashion. Drawbenches in which steel shapes or tubes are reduced in cross section by pulling them through a die, have customarily been driven by direct-current motors because of the speed adjustment obtainable by their use. With some modifications the two-speed alternating-current motor developed for elevator service was made suitable for draw bench duty, bringing to it the simplicity and low first cost of alternating-current motors and control. One such draw bench, built by the Aetna Standard Engineering Co. for the Sommerill Tubing Co. of Bridgeport, Pa., uses as the main drive a 100/50-hp., 1200/600-rpm. Westinghouse squirrel-cage induction motor, and a gear change device to obtain four operating speeds. This motor and control had to meet the stringent limitation of not exceeding six amperes per horsepower current inrush when starting or changing from one speed to another.

STEEL INDUSTRY TO SPEND MILLIONS ON NEW CONSTRUCTION

▲ Expenditures of companies in the steel industry for new equipment and construction will total at least $165,000,000 during 1938, according to reports received by the American Iron and Steel Institute from 120 companies comprising more than 90 90 per cent of the total capacity of the industry.

During 1937 the industry spent approximately $320,000,000 for such purposes, or about $30,000,000 more than the amount estimated by the industry in January 1937 as the sum to be spent for new equipment during that year.

The prospective decline from the 1937 total reflects not only the current low level of operations, but also

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ADVERTISING PAGES REMOVED

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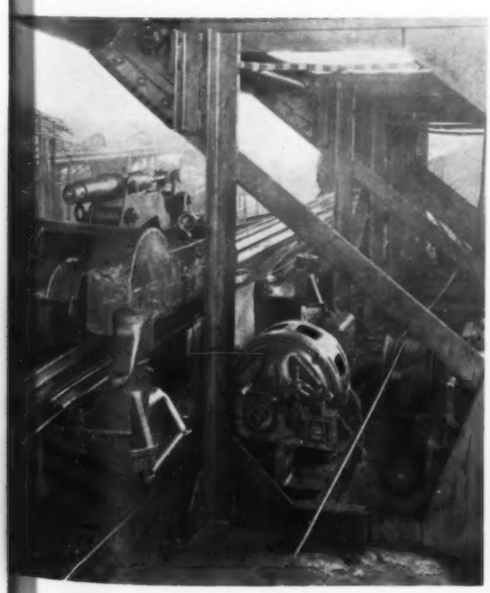

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The prospective decline from the 1937 total reflects not only the current low level of operations, but also

the fact that many companies completed large expansion programs during 1937. For example, three continuous mills for hot-rolled products, costing more than $20,000,000 each, were completed last year, whereas only one such mill is now under construction.

Announcement of the expected expenditures of steel companies in 1938 for expansion and improvement of properties raises the total spent or to be spent for such purposes in the four years 1935-1938 to more than $840,000,000. Of this sum, approximately $140,000,000 was spent in 1935; about $216,000,000 in 1936, and $320,000,000 last year.

The possibility that more than $165,000,000 may be spent for new equipment during 1938 is indicated by statements from a number of companies that their expenditures might increase if business conditions improve sufficiently and if there is an early revision of the provisions of tax laws which now discourage the use of earnings for such expenditures.

Improvements in steel-producing facilities which are scheduled for 1938 cover many branches of the manufacturing operations of the industry.

Capacity for producing pig iron will be augmented by the completion of new blast furnaces and the modernization and enlargement of older furnaces. Construction of at least one new battery of coke ovens is planned.

Expansion during 1938 of open-hearth steel ingot capacity is also indicated by plans calling for the construction of ten new furnaces and the rebuilding of more than a score of existing furnaces.

Plans calling for the construction of a number of new rolling mills have also been announced. Besides the construction of a continuous mill for hot-rolling sheet and strip steel, new mills for rolling slabs, plates and bars will be built.

Additions to the capacity of the industry for finishing cold rolled sheets and strip are also contemplated. Several cold mills of the reversing type will be built during the year, as well as three or four continuous cold rolling mills.

NEW HANDBOOK ON WELDING AVAILABLE

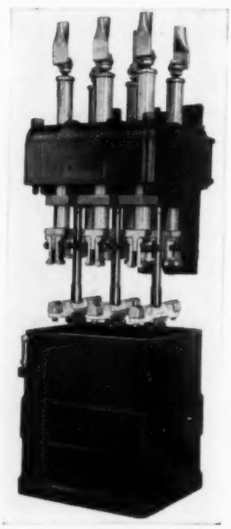
▲ "Procedure Handbook of Arc Welding Design and Practice," fifth edition just announced by The Lincoln Electric Company, Cleveland, Ohio, contains 1012 pages and a total of 1243 illustrations including photographs and drawings. The Handbook is reissued each year to include all new data essential for most efficient use of arc welding in all its varied applications.

Encyclopedic in scope, concisely written and profusely illustrated, the handbook is the complete arc welding reference guide. Written especially for use of designers, engineers, architects, production managers, welding supervisors and operators, the handbook contains a wealth of data of interest to draftsmen, steel fabricators and erectors, foremen, cost estimators, maintenance managers, shipbuilders, piping and pipe line contractors and students of welding.

MODERATE CAPACITY OIL CIRCUIT BREAKER

▲ Allis-Chalmers Manufacturing Company, Conduit Works, Boston, Massachusetts, announces a moderate capacity indoor oil circuit breaker of non-oil-throwing construction capable of wide application to industrial and central station service known as type DX-25. Expulsion ports, featured in this breaker, are devices which, it is claimed, hasten arc extinction. Other features include; self-aligning, wedge and finger type contacts with silver surfaces on main contacts; cast steel top frame, electrically welded steel tank; one-piece, Bakelain bushings; flat angle, straight line-motion type mechanism. The breaker is furnished manually or electrically operated for 600, 1200 and 2000 amperes at 15,000, 7,500 and 5000 volts respectively. It has an interrupting capacity rating of 75,000 kva.

Moderate capacity indoor oil circuit breaker of non-oil-throwing construction.



MODERN BLAST FURNACE FOR FAR NORTH

▲ Freyn Engineering Company is about to add the farthest north modern blast furnace to the list of Freyn Design blast furnaces at the other three extremities of the world. Messrs. Colvilles, Ltd., have arranged for the construction, by Messrs. Ashmore, Benson, Pease & Co. Ltd., British associates of the Freyn Engineering Company, for the construction of a furnace of nominal five hundred ton capacity, together with all auxiliary plant, at Glasgow, Scotland. This will be the first of two duplicate furnaces projected for construction at its Clyde Iron Works, replacing older furnaces and materially enlarging the plant output. The new furnace will be similar in size and general character to the Freyn Design furnace built by Ashmores for the Ford Motor Company at Dagenham, near London, England, in 1930.

CONVEYOR BULLETIN

▲ Standard Conveyor Company of North St. Paul, Minnesota has just issued an interesting and informative bulletin on conveyors for steel mill foundry and machine shop handling problems.

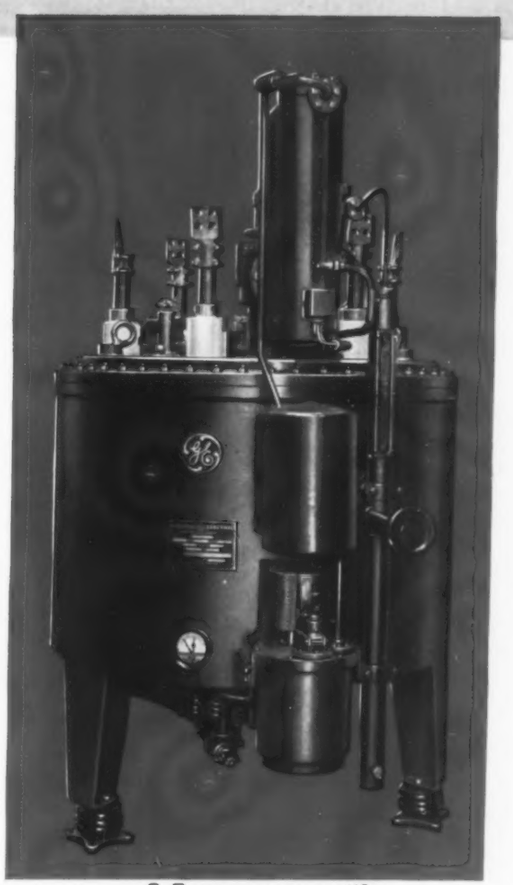
Many illustrations are included showing successful installations of conveyors and the handling of heavy concentrated loads in accord with the principle of uninterrupted flow of

(*Continued on page 72*)

THE RELIABILITY OF G-E RECTIFIERS IS BACKED BY 350,000 KW OF EXPERIENCE

TO GIVE YOU THESE ADVANTAGES IN POWER-CONVERSION SERVICE:

1. CONTINUOUS OPERATION
2. HIGH EFFICIENCY
3. LOW MAINTENANCE
4. EASE OF INSTALLATION
5. AUTOMATIC OPERATION
6. RESISTANCE TO CORROSION
7. LIGHT WEIGHT
8. NO SPECIAL FOUNDATIONS
9. NO ROTATING PARTS
10. NO COMMUTATION DIFFICULTIES



G-E mercury-arc rectifier

THE reliability of G-E mercury-arc rectifiers is demonstrated daily by the performance of 350,000 kw in successful service.

Reliability, combined with the many other advantages listed above, makes these rectifiers unusually well-suited for industrial power-conversion service.

Furthermore, they meet the *individual* requirements of many industries. For example, their construction enables them to withstand the corrosive atmosphere often present in *electrochemical* plants. In *steel-mill* service, their light weight and compact cooling system eliminate the necessity for expensive foundations and recirculating air systems. Their high part-load efficiency, as well as the features just mentioned, makes them highly suitable for *mining* operations.

The superiority of G-E rectifiers lies in an outstandingly sturdy construction that includes numerous refinements of design. The electric circuit, for example, is introduced into the tank through mycalex anode seals—an exclusive feature of G-E rectifiers. Because these seals are electrically welded to the tank cover, there are no mechanical joints, and a *permanent* anode construction results.

For further information, call the nearest G-E representative or write General Electric, Dept. 6—201, Schenectady, N. Y., for Publication GEA-1151B.

GENERAL ELECTRIC

280-5

material through the various steps in the manufacturing process.

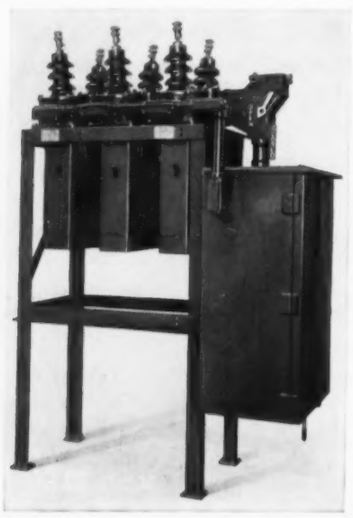
Numerous improvements in the mechanical features of conveyors to increase performance and service life are also explained and illustrated.

The bulletin will prove a valuable reference book to production and plant executives concerned with material handling problems in steel mills, foundries, and machine shops.

OUTDOOR TYPE OIL CIRCUIT BREAKER

▲ Allis-Chalmers Manufacturing Company, Conduit Works, Boston, Massachusetts, announces a new moderate capacity outdoor oil circuit breaker of the quick clearing, non-oil-throwing design, known as the type OZ-110. Special interrupting devices called Ruptors are used to give quick clearing of short circuits, low arc energy, low pressure, and minimum of oil deterioration. Other features are: Rigid cast steel top frames; silver contact surfaces; low-inertia, straight-line-motion type mechanisms; high speed operator; roomy, weather-proof control cabinet; one-piece, wet process porcelain bushings. The breaker is furnished for 600 amperes at 15 kv., with an interrupting capacity rating of 100,000 kva. It is arranged for pole or frame mounting.

Moderate capacity outdoor oil circuit breaker of quick clearing, non-oil-throwing design.



LARGEST BATTERY OF BELL-TYPE FURNACES

▲ The largest battery of cylindrical bell-type furnaces in the world is used for bright annealing coiled strip in the Rouge Plant of the Ford Motor Company. The recent addition of 12 Westinghouse bell-type furnaces make a total of 38 furnaces with an annealing capacity of approximately 600 tons per day and a total connected load of 8510-kw.

Each furnace is rated at 230-kw. with a capacity for annealing two coils 52″ in diameter and 48″ in height, giving a total of 16 tons per charge. The coils are heated from the inside as well as the outside, utilizing both radiation and convection. Temperature uniformity of the order of 20° F. maximum variation is obtained. This characteristic obviates distortion even though the coils are not thermally saturated in routine annealing. The net thermal efficiency is approximately 80%.

RESISTANCE WELDING BOOKLET AVAILABLE

▲ Ways of increasing profits with improved welding quality are suggested in a new Westinghouse 12-page pamphlet, entitled, "New Profits from Resistance Welding with Ignitron Split-Second Control."

Ignitron controls are available for spot, seam, butt and projection welding operations, and for applications requiring a single welder for both spot or seam welding. Suggestions for handling unusual welding jobs needing frequent heat adjustment, or different current and time values are discussed in this booklet.

Illustrations include actual installations of ignitron controls for fabricating large and small parts; also, typical parts and products of steel, stainless steel, aluminum and other metals and alloys welded on a production basis are shown.

Copies may be secured from the nearest district office of Westinghouse Electric & Manufacturing Company or from headquarters at East Pittsburgh, Pennsylvania.

NEW THREE-HIGH SHEET MILL ORDERS

▲ Continental Roll & Steel Foundry Co., Pittsburgh, has received orders for two complete three-high mechanized sheet mill units. One of the units, to be used as a finishing sheet mill, will go to Continental Steel Co., Kokomo, Ind., and the other, a sheet break down mill, is for superior Sheet Steel Co., Louisville, Ohio.

▲ Lewis Foundry & Machine Division of the Blaw-Knox Company, has received a contract for two balanced three-high rolling mills, equipped with automatic screw down, from Bengal Steel Company, Limited, of India. This makes a total of 11 orders for three-high mills received in the past 12 months.

NEW BOOK ON INSULATION

▲ The Okonite Company, manufacturers of insulated wires and cables, of Passaic. New Jersey, have published a new book entitled "Okonite Insulation." It describes not only how Okonite rubber insulation is made, but also gives tables on resistance, thicknesses, diameters and installation data pertinent to rubber insulated cables for service up to 5,000 volts.

ISSUE BROCHURE ON COMBUSTION CONTROL

▲ The Hays Corporation, Michigan City, Indiana, has just issued a 40-page brochure on Centralized Combustion Control for steam power plants. As a supplement, an 8-page pamphlet is being offered on the designing and manufacturing of boiler room panels. The two publications afford a most complete exposition of modern combustion control methods and are available to all who are interested in the subject.

ADVERTISING PAGES REMOVED

ASSOCIATION OF IRON AND STEEL ENGINEERS

(ORGANIZED 1907 AS ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS)

EMPIRE BUILDING · PITTSBURGH

President
L. F. COFFIN,
Supt. Mech. Dept.
Bethlehem Steel Company,
Sparrows Point, Md.

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OF DIRECTORS
1938

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2ND VICE PRES., W. A. PERRY, *Supt. Elec. and Pwr. Depts., Inland Steel Company, Indiana Harbor, Indiana.*
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DIRECTOR, A. W. STEED, *Maintenance Supt., American Rolling Mill Company, Middletown, Ohio.*

Managing Director
BRENT WILEY
Empire Bldg., Pittsburgh

Membership Campaign Goal

A NEW MEMBER BY EACH MEMBER IN THE NEXT 90 DAYS

Dear Member:

As chairman of the membership committee of the Association of Iron and Steel Engineers, I am hereby appointing you as a committee of one to have at least one or more eligible persons apply for membership in our Society within the next ninety-day period.

Please cite to the eligible prospects the many advantages to be gained from affiliation with our Society. The Association is now starting its 31st year of rendering service to the Iron and Steel Industry with greatly amplified activities and to insure that these plans will be carried on, it is vitally necessary that we have the fullest of cooperation from all those associated with the industry.

Upon these premises we are soliciting your aid in obtaining new members, particularly the younger men. The addition of new members means increased interest in the Association's activities, and thus an increase in its usefulness to each member as well as to the Steel Industry.

If each and every member takes upon himself the responsibility of obtaining one new member, the Association will be making marvelous strides. Let's all pull together and put this campaign over!

Yours very truly,

GRC:MM
Encl.

G. R. Carroll

G. R. CARROLL,
Chairman
Membership Committee
A. I. & S. E.

This letter has been sent to every member in the Association. It is sincerely desired that this Campaign will prove effective.

ITEMS OF INTEREST

Howard G. McIlvried has been appointed general superintendent of Irvin Works, new sheet, strip and tin plate plant under construction near Clairton, Pennsylvania.

Mr. McIlvried, associated with subsidiary companies of the United States Steel Corporation for many years, began as a machinist at the Braddock, Pennsylvania, Works of American Steel and Wire Company, and later was connected successively with the engineering departments of the Wire, National Tube, Carnegie Steel and American Sheet and Tin Plate companies. He was named chief engineer of the tin plate company in 1931, and later became assistant to the vice president. Upon consolidation of the sheet and tin company with Carnegie-Illinois, Mr. McIlvried was on June 1, 1936, appointed assistant manager of Chicago district operations. In February, 1937, he was transferred to Pittsburgh as assistant to the manager of operations and continued in that position until his current appointment.

▲

Charles R. Moffat was appointed director of advertising, under C. V. McKaig, vice president, of the United States Steel Corporation of Delaware. Mr. Moffat has been advertising manager of Carnegie-Illinois Steel Corporation since the organization of that company October 1, 1935, and director of exhibits of United States Steel Corporation since July 1, 1935. He moves into his new position after thirty-one years of service with subsidiary companies, beginning in 1907, in the accounting department of the Illinois Steel Company at Chicago. He assumed charge of sales statistics and advertising of that company in 1919, and remained in that position until his 1935 appointments. Mr. Moffatt will be located at 436 Seventh Avenue, Pittsburgh, Pennsylvania.

▲

G. Reed Schreiner, formerly assistant advertising manager of the Carnegie-Illinois Steel Corporation, was appointed advertising manager, succeeding Charles R. Moffatt, now director of advertising of United States Steel Corporation of Delaware. Mr. Schreiner, was born in Pittsburgh, in June 1895, and received his A.B. degree at the University of Pittsburgh in 1916. Following service in the World War, he entered the advertising department of the former Carnegie Steel Company in January 1919, and has served continuously with that department of the United States Steel Corporation subsidiary.

▲

Charles B. Patt, assistant superintendent at the Donora, Pa., works of American Steel & Wire Co. for over five years, has been appointed superintendent of the company's Allentown, Pa., works, succeeding the late James S. Phifer. Mr. Patt started working for the Wire company in September, 1905, as a clerk in the order and warehouse department. He filled various positions with the company until in 1931 he was appointed manager's representative at Pittsburgh, which post he held until being made assistant superintendent at Donora in September, 1932. Born in Shelbyville, Ill., on March 11, 1884, Mr. Patt attended Doane academy at Granville, O., and later attended Denison university, being graduated with an A.B. degree.

H. G. McILVRIED

C. R. MOFFAT

G. R. SCHREINER

J. M. SIAS

L. E. FEISNER

J. S. NACHTMAN

J. M. Sias was appointed assistant vice-president, raw materials department, of the United States Steel Corporation of Delaware. Mr. Sias began his business career in the auditing department of Carnegie Steel Company in 1893, and transferred to the company's raw materials department six years later. He went to the New York offices of the United States Steel Corporation of New Jersey as assistant to the vice-president, raw materials, in 1909, and in recent years has been assistant to the vice-president in charge of operations for the New Jersey corporation.

▲

L. E. Feisner has accepted a position as operating superintendent of the new continuous hot strip mill at Zaporojstal, Russia. A new 66-inch hot and cold strip mill at this plant is expected to go into operation about the end of February. Before this appointment, Mr. Feisner was superintendent of the Jones and Laughlin Steel Corporation's new 96″ continuous hot strip mill, at Pittsburgh. He started his career in the steel business at the Wheeling Steel Corporation in 1925. When he left the Wheeling Steel Corporation in 1936, he was assistant superintendent of the hot strip department.

▲

S. E. Graeff, assistant general superintendent, American Rolling Mill Company, East Works, Middletown, Ohio, has accepted the position of assistant to general manager, Richard Thomas Company, Ltd., Ebbw Vale, Monmouthshire, England.

▲

Cecil Warrender, who resigned recently as assistant director of the rolling department of the Carnegie-Illinois Steel Corporation in Chicago, has been made superintendent of the slab and strip mills now under construction for Richard Thomas Tin Plate Company at Ebbw Vale, Wales. He will sail from New York late this month.

J. S. Nachtman will be in charge of the newly formed Electrochemical Processes Division of the Blaw-Knox Company, with offices at Groveton, Pennsylvania. Mr. Nachtman, formerly president of the Electrochemical Processes Company of Youngstown, Ohio, was graduated from the Colorado School of Mines. He was associated with the American Steel and Wire Company and the E. W. Bliss Company, following graduation. He then became superintendent in charge of electroplating at the plant of the Thomas Steel Company, at Warren, Ohio.

The new Division under Mr. Nachtman's supervision will produce equipment for continuously plating tin, nickel, brass, bronze, terne plate, copper, etc., on steel and for the continuous cleaning and pickling of strip, sheet and wire, including rust-proofing and coloring.

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Theodore F. Smith, formerly vice-president of the Oliver Iron and Steel Corporation, was elected executive vice-president of that company. Charles Fassinger, Sr., vice-president in charge of operations, was appointed vice-president in charge of development and research; Morgan Kavanagh, formerly of Cleveland, Ohio, succeeds Charles Fassinger, Sr., in the capacity of general plant manager.

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N. B. Ornitz was recently made the president of the Power Piping Division of the Blaw-Knox Company. Mr. Ornitz, a director and a vice-president of the Blaw-Knox Company, will also continue the management of the National Alloy Steel Division of the Blaw-Knox Company.

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W. N. Quartz has been appointed vice-president in charge of operations of the Power Piping Division of the Blaw-Knox Company.

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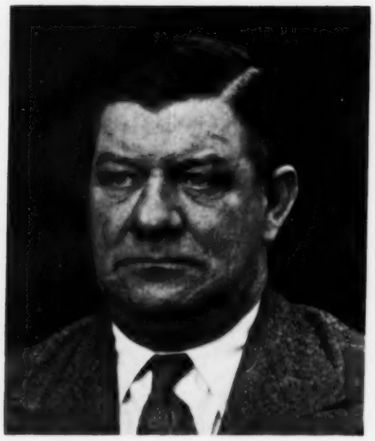
McKeesport Tin Plate Corporation recently announced the following changes in their personnel: Hugh G. Gibson, formerly chief engineer, is now

ALLEN W. MORTON



J. L. KEENAN

H. B. CUMMINGS

JAMES R. BOTTOMS

assistant general superintendent; William H. Craighead, formerly assistant master mechanic, became chief engineer; Fred A. Anderson, machine shop foreman, was made master mechanic; Frank E. Hopke, boiler department foreman, was appointed assistant master mechanic; and Carl Michaels, who formerly was connected with the Carnegie-Illinois Steel Corporation, was made Tin House superintendent of the McKeesport Tin Plate Corporation.

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Dr. Chauncey Guy Suits, research physicist of the General Electric Research Laboratory, has been selected as America's outstanding young electrical engineer for the year 1937, according to an announcement by Eta Kappa Nu, honorary electrical engineering fraternity. Dr. Suits' selection was made from a group of sixty candidates less than thirty-five years of age, submitted by leading industrialists and educators.

Dr. Suits was born in Oshkosh, Wisconsin, in 1905, and was graduated from the University of Wisconsin in 1927. He obtained his Sc. D. from Zurich in 1929, and then became a member of the General Electric Research Laboratory staff at Schenectady, New York.

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J. L. Keenan, who served in the works of the Tata Iron and Steel Company, Ltd., Jamshedpur, India, for twenty-five years, and who for the last eight years was general manager of the company, has retired from service. The Jamshedpur Steel Works is one of the largest single steel units in the British Empire, controlled and managed by natives of India. It was largely through the efforts of Mr. Keenan and his assistants that Jamshedpur became the Pittsburgh of India.

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Carle Vande Bogart, formerly of the New Haven sales office of the Rockbestos Products Corporation, is now in charge of the Chicago office of that company in the Stephenson Building, Chicago, Illinois.

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Allen W. Morton recently was elected vice president of the Koppers Company. Mr. Morton will continue in charge of Koppers' American Hammered Piston Ring Division at Baltimore, Maryland, where he has been general manager. A native of Richmond, Virginia, Mr. Morton was graduated from the University of Virginia, as a civil engineer, in 1916. That year he was employed by the Bartlett Hayward Company, Baltimore, now a division of the Koppers Company. He later became associated with the American Hammered Piston Ring Division of the same company.

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A. L. Bergstrom, following the resignation of Ernest Wooler, chief engineer of the Timken Roller Bearing Company, has been appointed executive engineer to coordinate some of the varied engineering activities of the company. Mr. Bergstrom was a graduate of the Royal Technical Institute of Sweden, and after his graduation spent several years with the Krupp organization in Germany. After a number of years in design work in this country, he became connected with the Timken Roller Bearing Company in 1929, in the works engineering department, advancing to the position of chief works engineer, which position he filled until his appointment as executive engineer of the company.

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Timken Roller Bearing Company recently announced several promotions in the various divisions: R. M. Riblet was appointed chief engineer of the automotive division; J. B. Baker, assistant chief engineer of the automotive division and chief engineer of the Rock Bit Division; S. M. Weckstein, chief

engineer of the industrial division; H. C. Edwards, chief engineer of the fuel injection equipment division; W. C. Makley, chief works engineer; and E. J. Reagan, general service manager.

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Howard B. Cummings has taken a position as engineer in the service engineering department of the United Engineering and Foundry Company, at Pittsburgh, Pennsylvania. Mr. Cummings started to learn the machinist trade in 1915, and during his apprenticeship he studied mechanical engineering at the Carnegie Institute of Technology evening school. In 1918 he served as apprentice master mechanic at the Aliquippa Works of the Jones and Laughlin Steel Corporation. He spent several years in the experimental department, and later was foreman of the Aliquippa South Mills Machine Shop. For the last four years he has been in charge of the tin plate cold reducing department at the same plant, the position he was holding at the time of his transfer.

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James R. Bottoms has accepted a position with Richard Thomas & Co., Ltd., Ebbw Vale, England, in connection with that company's new hot and cold strip mill. He will be manager of the hot and finishing mill operations.

Before this appointment he was superintendent of the Jones & Laughlin Steel Corporation's cold strip mill department. He started with the American Rolling Mill Company at Ashland, Ky., in 1923. In 1930 he became superintendent of processing at the Butler strip mill. He subsequently worked for Republic Steel Corporation and later at Wheeling Steel Company as assistant superintendent of the cold strip mill department. He held the latter position until October, 1936, when he joined Jones & Laughlin.

Mr. Bottoms is a member of the Association of Iron and Steel Engineers.

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George A. Hileman, formerly assistant superintendent of maintenance of the Carnegie-Illinois Steel Corporation, Vandergrift, Pennsylvania, has been made the superintendent of maintenance at that plant. Mr. Hileman succeeds George Croft who has accepted a position with Blaw-Knox. Other personnel changes at the Vandergrift Works are as follows: George S. Zorn, formerly general maintenance foreman, now assistant superintendent of maintenance; Russell Penrod, boiler shop foreman, now general maintenance foreman; Glenn White, assistant foreman, now boiler shop foreman; and Joseph C. McGrath, observer, now assistant boiler shop foreman.

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Robert Sergeson has just joined the Staff of the Crucible Steel Co. of America as chief metallurgist of its Park works, in Pittsburgh. He was formerly associated with the Republic Steel Corp., with which he had a wide and varied experience in the production and use of stainless and alloy steels.

Obituaries

Willard P. Chandler, Jr. died January 24 at his home, in Pittsburgh. Mr. Chandler was chief engineer of the industrial division of the Blaw-Knox Division of the Blaw-Knox Company, and had been in the employ of the company since January 1929. Before coming with Blaw-Knox, he was identified with the American Heat Economy Bureau and prior to that respectively with Duquesne Steel Works and Clairton Steel Works of the Carnegie-Illinois Steel Corporation.

WILLARD P. CHANDLER, JR.

Mr. Chandler was a member of the Association of Iron and Steel Engineers, the American Iron and Steel Institute, and the Engineers Society of Western Pennsylvania.

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Charles Waterman Stone, 63, consulting engineer of the General Electric Company, died at his home in Schenectady, New York on February 3. After his graduation from the University of Kansas in 1894, Mr. Stone was with the Franklin Electric Company of Kansas City, the W. S. Hill Electric Company of New Bedford, Massachusetts, and the Hancock Equipment Company of Boston, two years each.

In 1900 he joined the General Electric organization in the drafting department, and in the following year was in switchgear engineering. Then he joined the lighting engineering department in 1904. Mr. Stone was named manager of the lighting department, now known as the Central Station department, in 1912. He continued in that position until 1928, when, at his own request he was relieved of managerial responsibilities and became a consulting engineer of the company. Mr. Stone was also active in the affairs of the Radio Corporation of America from the time of its inception, and in 1927, while still manager of the central station department, was named assistant to the president of the radio corporation.

Jones & Laughlin ANNOUNCE *Personnel Changes*

Jones & Laughlin Steel Corporation announced the resignation of S. E. Hackett as president, director and member of the executive committee.

The corporation at the same time announced the election of H. E. Lewis as president, which office he will hold in addition to his present post as chairman of the board.

The corporation also announced the election of Lewis M. Parsons as a director of the corporation and vice president in charge of sales, effective March 1. Parsons has been with the Bethlehem Steel Company for many years, lately in charge of its Philadelphia sales office.

Mr. Hackett became president of Jones & Laughlin in 1934 after having been vice president in charge of sales since 1923. He succeeded the late George Gordon Crawford in the presidency.

Mr. Hackett's original connection with Jones & Laughlin was in 1916 when he was made manager of the Chicago warehouse and Chicago district sales manager. Prior to that time he had been with Joseph T. Ryerson & Sons, Inc., of Chicago as manager of orders and later as purchasing agent.

Mr. Hackett was transferred to the Pittsburgh office of Jones & Laughlin in 1918 as general manager of sales. Five years later he was made vice president in charge of sales and a director of the company.

H. E. Lewis is widely-known in the steel industry and versed in finance as well as operations. Born in Wales, he came to this country in early childhood, worked for the Carnegie Steel Company in Pittsburgh, then went with Bethlehem, becoming vice president. He was chairman of the executive committee of the Jeffrey Manufacturing Company, Columbus, Ohio, at the time of his appointment as chairman of the board of Jones & Laughlin in 1936.

S. E. HACKETT

H. E. LEWIS